ORDER

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(Includes Chgs 1-3)

MAINTENANCE OF ELECTRICAL POWER AND CONTROL CABLES

FEBRUARY 8, 1978

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

Distribution: FAF-0(Wide),RAF-3,ZAF-607,ZAC-328   Initiated By: AAC-1010

CHANGE

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

6950.22 CHG 1

11/16/79

Cancellation Date: Retain

SUBJ: MAINTENANCE OF ELECTRICAL POWER AND CONTROL CABLES

This change decreases the frequency of periodic testing and authorizes an alternate cable tester when a high voltage cable tester is unavailable.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
iii and iv	2/8/78	iii	2/8/78
		iv	11/16/79
11 and 12	2/8/78	11	2/8/78
		12	11/16/79
13 and 14	2/8/78	13	11/16/79
		14	2/8/78
17 and 18	2/8/78	17	2/8/78
		18	11/16/79
37 thru 42	2/8/78	37 thru 42	11/16/79
43 and 44	2/8/78	43	11/16/79
		44	2/8/78
91 and 92	2/8/78	91	11/16/79
		92	2/8/78

James McAynn (signature)

JAMES BISPO
Director, Airway Facilities Service

Distribution: A-FAF-O(MAX); A-X(AF)-3; ZAF-607; ZAC-328 Initiated By: AAC-1010

CHANGE

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

6950.22 CHG 2

4/10/80

Cancellation Date: Retain

SUBJ: MAINTENANCE OF ELECTRICAL POWER AND CONTROL CABLES

This change revises cable splicing procedures for electrical power and control cables.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
iii thru vi	2/8/78	iii	2/8/78
		iv	4/10/80
		v	4/10/80
		vi	2/8/78
7 and 8	2/8/78	7	2/8/78
		8	4/10/80
25 thru 28	2/8/78	25	2/8/78
		26	4/10/80
		27	2/8/78
		28	4/10/80
47 thru 58	2/8/78	47 thru 54-2	4/10/80
		55	4/10/80
		56	2/8/78
		57	2/8/78
		58	4/10/80
65 thru 68	2/8/78	65	4/10/80
		66	2/8/78
		67	2/8/78
		68	4/10/80
69 thru 74	2/8/78	69	2/8/78
		70	4/10/80
	2/8/78	71	2/8/78
		72	4/10/80
		73	4/10/80
		74	2/8/78
77 thru 82	2/8/78	77	2/8/78
		78	4/10/80
		79	4/10/80
		80	2/8/78
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PAGE CONTROL CHART (continued)

Remove Pages	Dated	Insert Pages	Dated
93 and 94	2/8/78	93	2/8/78
		94	4/10/80
		94-1/94-2	4/10/80

Donald A. Schroeder

for GERALD L. THOMPSON
Director, Airway Facilities Service

CHANGE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

6950.22
CHG 3

11/30/84

SUBJ: MAINTENANCE OF ELECTRICAL POWER AND CONTROL CABLES

1. PURPOSE. This change includes the use of Sigmaform Corporation heat-shrinkable tubing for splicing electrical power and control cables.

2. DISPOSITION OF TRANSMITTAL. Retain this transmittal.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
49 and 50	4/10/80	49	11/30/84
		50	4/10/80
89 and 90	2/8/78	89	11/30/84
		90	2/8/78
93	Undated	93	Undated
94	4/10/80	94	11/30/84
95 and 96	2/8/78	95	2/8/78
		96	11/30/84

Martin T. Pozesky, for
Martin T. Pozesky
Director, Program Engineering
and Maintenance Service

Distribution: A-FAF-O(MAX); A-X(AF)-3; ZAF-607

Initiated By: APM-154

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FOREWORD

1. PURPOSE.
This order provides guidance and prescribes technical standards and tolerances, and procedures applicable to the maintenance and inspection of electrical power and control cables. It also provides information on special methods and techniques that will enable maintenance personnel to achieve optimum performance from the equipment. This information augments information available in instruction books and other handbooks, and complements the latest edition of Order 6000.15, Maintenance of Airway Facilities.

2. DISTRIBUTION.
This directive is distributed to selected offices and services within Washington headquarters, NAFEC, and the Aeronautical Center; to branch level within regional Airway Facilities divisions, and to Airway Facilities field offices having responsibility for the maintenance of electrical power and control cables.

3. CANCELLATION.
AF P 6950.6, Maintenance and Repair of Power and Control Cables and AF P 6950.9, Maintenance Evaluation of Electrical Systems are canceled.

4. MAJOR CHANGES.
This order revises and updates all information contained in AF P 6950.6 and AF P 6950.9.

5. MAINTENANCE AND MODIFICATION POLICY.

a. Order 6000.15, this order, and the applicable equipment instruction book shall be used by the maintenance technician in all duties and activities for the maintenance of power and control cables. The three documents shall be considered collectively as a single official source of maintenance policy and direction authorized by the Airway Facilities Service. References located in the chapters of this order entitled Standards and Tolerances, Periodic Maintenance, and Maintenance Procedures shall indicate to the user whether this order and/or the equipment instruction book shall be consulted for a particular standard, key inspection element or performance paramenter, performance check, maintenance task, or maintenance procedure.

b. The latest edition of Order 6032.1, Modifications to Ground Facilities, Systems, and Equipment in the National Airspace System, contains comprehensive policy and direction concerning the development, authorization, implementation, and recording of modifications to facilities, systems, and equipment in commissioned status. It supersedes all instructions published in earlier editions of maintenance technical orders and related directives.

6. CREDIT FOR USE OF COPYRIGHT MATERIAL.
The following brochures and drawings have been reprinted in total, or in part, by permission from the 3M Company, Saint Paul, Minnesota.

a. 34-7000-9215-7 — Instructions for 82-A1 kit

b. E-MC2047-X1-1 — Drawing

c. E-MC2047-X39-1 — Drawing

d. E-MC2047-Y11-1 — Drawing

e. E-MC2047-Z15-1 — Drawing

f. E-MC2474-X3 — Drawing

7. RECOMMENDATIONS AND CHANGES.
Preaddressed comment sheets are provided at the back of this order in accordance with the latest edition of Order 1320.40, Expedited Clearance Procedures for Airway Facilities Maintenance Directives. Users are encouraged to submit recommendations for improvement.

8. FILING INSTRUCTIONS.
This handbook is required at all Airway Facilities

sectors; AF structures and ground groups and field maintenance parties; and sector field offices, field units, and field office units for general reference and use. At the opinion of the regional Airway Facilities divisions, this handbook may be distributed to a lower level.

for WARREN C. SHARP
Director, Airway Facilities Service

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

DATE:

IN REPLY REFER TO:

SUBJECT: Suggested improvements to Order 6950.22, Maintenance of Electrical Power and Control Cables

FROM:

TO: Chief, Environmental Systems Division, AAF-500

Problems with present order.

Recommended improvements.

Signature

Facility Identifier and AF Address

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

DATE:

IN REPLY REFER TO:

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CHAPTER 1. GENERAL INFORMATION AND REQUIREMENTS

1. OBJECTIVE.

This handbook provides the necessary guidance, to be used in conjunction with information available in instruction books and other directives, for the proper maintenance of FAA electrical power and control cables.

2. SCOPE.

This handbook establishes standards and procedures for maintenance, repairs, and replacement of component parts for electrical power and control cables used throughout the National Airspace System.

3. INSPECTION AND MAINTENANCE PROGRAM.

This order requires that an adequate inspection and maintenance program be established to permit the timely detection and correction of deficiencies to eliminate major repairs. The intent of a well-organized maintenance program is to achieve maximum life and serviceability. It is not intended that this life and serviceability be achieved through costly over-maintenance. Planning and sound judgment must be exercised to maintain cable standards.

4. SAFETY.

The possibility of electrical shock, falls from elevated structures, and other hazards are ever present while performing maintenance. Therefore, personnel shall be particularly mindful of these dangers and shall observe the safe practice recommendations contained in the latest edition of Order 6000.15, Maintenance of Airway Facilities.

5. MAINTENANCE DRAWINGS AND RECORDS.

Current records must be maintained on the location and condition of all facility cables. The following items provide a valuable record: test readings made at the time of each cable installation; a complete set of "as built" drawings showing the exact location of cable routes, ducts, manholes, handholes, terminations, test points, switches, cable sizes and types, color coding, and other system component features; and a continuous record of the condition of every facility cable. It is the responsibility of each sector to update and maintain facility drawings and records.

6.-9. RESERVED.

CHAPTER 2. TECHNICAL CHARACTERISTICS
Section 1. CABLE CONSTRUCTION

10. GENERAL.

There are many different power, control, telephone-type, and coaxial cable constructions on the market today; and all of them require at least two terminations and possibly one or more splices. While it is virtually impossible to be familiar with each cable construction, all of the components in a cable are used for a specific reason and perform the same function even though the materials may be different. It is, therefore, important to understand the basic functions of the various cable components and know what materials to use for splices and terminations.

11. POWER CABLE CONSTRUCTION.

a. Typical Power Cables. Figure 2-1 shows a typical single-conductor nonshielded power cable, a single-conductor shielded cable, and a three-conductor shielded cable.

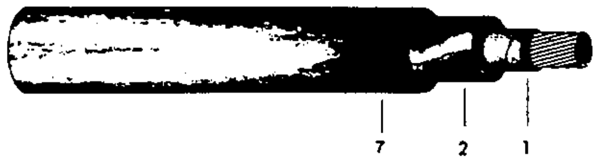
(1) Conductors. The principal factors to consider in selecting a conductor are materials, flexibility and shape, size, and shielding.

(a) Materials. Copper and aluminum are the two most commonly used conductor materials.

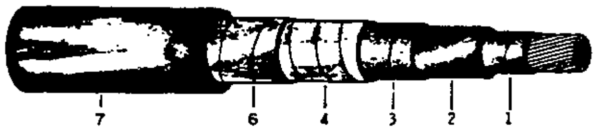
1 **Copper.** Because of its high conductivity, ready workability, and ease of handling, annealed copper (tinned or lead-alloy coated when used with rubber) generally has been used.

2 **Aluminum.** Aluminum is lighter in weight than copper and may actually result in a lower initial cost. However, due to the lower conductivity of aluminum, a larger size is required to supply a given load. Also, an oxide rapidly forms on the surface of aluminum strands, which insulates them from each other and makes splicing and terminating difficult. Aluminum will also cold-flow and is damaged by galvanic action when connected to other metals where moisture is present.

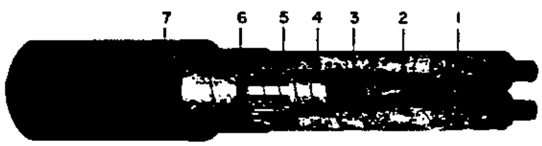
(b) Conductor Flexibility and Shape. Cable conductors are either solid or stranded. A solid conductor is used in cables of smaller sizes. When greater flexibility is desired for larger conductor cross-sectional areas, a number of strands are grouped together to equal the desired conductor cross-sectional area. The greater the number of strands, the greater the flexibility of a given conductor size. Conductors for insulated cables in sizes



NONSHIELDED CABLE



SHIELDED POWER CABLE



THREE-CONDUCTOR SHIELDED POWER CABLE

1. STRAND SHIELDING
2. INSULATION
3. SEMICONDUCTING MATERIAL
4. METALLIC SHIELDING
5. FILLER MATERIAL
6. BEDDING TAPE
7. CABLE JACKET

Figure 2-1. Construction of Power Cables.

No. 6 American Wire Gauge (AWG) and larger are stranded. This is a requirement specified by the National Electrical Manufacturers Association-Insulated Power Cable Engineers Association (NEMA-IPCEA) Standards. Figure 2-2 shows the most common shapes of stranded conductors.

1 **Concentric Round.** A concentric round cable is formed by wrapping the same size conductors concentrically around a single conductor.

2 **Compact Round.** The compact round cable has a smaller overall diameter for the same number of conductors, but is less flexible than the concentric round cable. The smaller diameter is obtained by laying all the strands in the same direction and then rolling each layer to eliminate the spaces.

3 **Compact Sector.** The purpose of the sector shape is to obtain a smaller diameter cable. It is normally made only with impregnated paper or varnished cambric insulation. Compact sector conductors are stiffer and more difficult to splice.

4 **Annular.** Annular conductors are usually composed of wires grouped concentrically around a rope-like cord. This construction is generally used for conductor sizes above 1000 MCM (thousand circular mil) to help combat skin effect or the tendency of current to flow more readily along the exterior of a cable. Since alternating current flows more densely near the surface of a conductor, especially at high voltages, distributing the conducting surface area around the exterior of the cable increases the current-carrying capacity.

5 **Segmental.** A segmental conductor is composed of three or four segments or groups of strands that are electrically separated from one another. This reduces the skin effect and results in a smaller diameter cable with greater current-carrying ability.

(c) **Conductor Size.** The size of a conductor is given either in AWG or MCM units. The AWG numbers decrease as the conductor physical sizes increase to a certain point, then the AWG numbers begin to increase. For example, as the conductor size increases, the AWG numbers decrease to AWG No. 1. At this point, as conductor physical sizes increase, AWG sizes increase from AWG Nos. 1/0 (0)to 4/0 (0000). From here on the increasing sizes are given in thousand circular mil units. A circular mil is the area of a circle 1/1000 of an inch in diameter. One thousand circular mils is usually abbreviated MCM, however, kcmil is also used. Thus, to find the area of a solid circular conductor in circular mils, multiply its diameter in inches by 1000 and square the product, or $A = (1000d)^2$.

(d) **Conductor Strand Shielding.** The purpose of a conductor strand shield is to prevent corona within air pockets between the conductor and its insulation. Corona can damage the insulation and is caused by ionization of air resulting from the presence of a high voltage electric field. During manufacture, strand shielding is applied between the conductor and the cable insulation. (See figure 2-1.) Strand shielding is made from materials such as conductive fibrous tapes, conducting paints, conducting rubber, and graphite compounds.

(2) **Conductor Insulation.**

(a) **Purpose.** To be useful and safe, electrical current must be made to flow only where it is needed. It must be channeled from the power source to a useful load. Current-carrying conductors should not be allowed to come in contact with one another, their supporting hardware, or personnel working near them. To accomplish this, conductors are coated or wrapped with various materials. These materials have such high resistance that they are, for all practical purposes, nonconductors. They are generally referred to as insulators or insulating material.

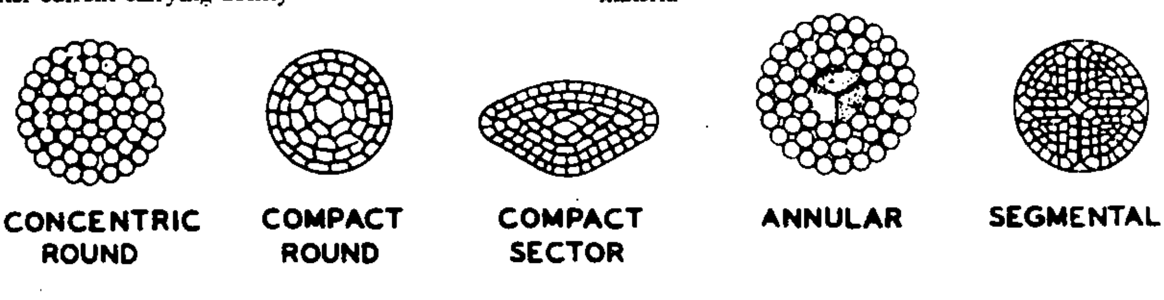


Figure 2-2. Common Shapes of Stranded Conductors.

(b) **Properties.** Two fundamental properties of insulation material are dielectric strength and insulation resistance. These are entirely different and distinct properties.

1 **Dielectric Strength.** Dielectric strength is the ability of insulation to withstand potential difference, and is usually expressed in terms of the voltage at which the insulation fails because of the electrostatic stress. Maximum dielectric strength values can be measured by raising the voltage of a test sample until the insulation breaks down.

2 **Insulation Resistance.** Insulation resistance is the resistance to current leakage through and over the surface of insulation materials. Insulation resistance can be measured by means of an insulation resistance tester without damaging the insulation. Information so obtained serves as a useful guide in determining the general condition of the insulation. However, the data obtained in this manner may not give a true picture of the condition of the insulation. For example, the present FAA minimum allowance on a 5kV conductor, having been in operation for 1 year, is 10 megohms between conductor or from any conductor to ground. In extremely dry conditions, a cable may test well above the minimum resistance. However, if the cable insulation had a minor defect and a test is made under moist conditions, the resistance may be much lower.

(c) **Insulation Materials.**

1 **General.** The three most common materials used as insulation for power cable are: natural rubber; ethylene-propylene rubber (EPR); thermoplastics, such as polyvinyl chloride, polyethylene; and thermosets, such as cross-linked polyethylene. The material best suited for a specific cable depends on many factors; such as, operating voltage, required ampacity, ambient temperature, type of installation, and cost.

2 **Rubber Insulation.** Rubber insulation compares with thermoplastic insulations as follows:

a Better flexibility at lower temperatures.

b Less flow under compressive forces at elevated temperatures.

c Dielectric strength higher than polyethylene, but lower than polyvinyl chloride.

d More susceptible to deterioration in sunlight, oil, ozone, and weathering than polyvinyl chloride, and hence requires a covering. For the same reasons, polyethylene requires a covering.

e Easier to join and terminate.

3 **EPR Insulation.** Ethylene-propylene rubber insulations are vulcanizable compounds that are made with EPR elastomer gums. Cables made with EPR insulations combine into one dielectric a moisture resistance similar to polyethylene, the dielectric strength retention of oil base compounds, and the heat and form stability of butyl insulations. These insulations are rated at 125° C for emergency or hot spot operation and a normal operating temperature of at least 90° C.

4 **Polyethylene Insulation.** Unlike the other insulations discussed herein, the best polyethylenes contain relatively small amounts, not over 3 percent, of material other than the base polymer. The insulation may contain coloring materials, and for exposure to sunlight and weather, should contain a small amount of carbon black. Polyethylene has low power-factor and dielectric loss, high dielectric and impulse strength, excellent moisture resistance, and high impact strength and abrasion resistance.

5 **Cross-Linked Polyethylene.** Cross-linked polyethylene represents a series of compounds consisting of polyethylene resin, fillers, antioxidants, and vulcanizing agents. It has most of the electrical advantages of polyethylene plus much better mechanical properties such as superior resistance to heat deformation and environmental stress cracking. The insulation thickness used on these cables is at least as thin as that of polyethylene power cables and in many cases much thinner. This is possible because of its exceptional dielectric strength. Most cross-linked polyethylenes are rated at 90° C at 15kV, with a 100-hour-per-year overload temperature of 130° C for 5 years of its life.

(3) **Insulation Shielding.**

(a) **General.** Insulation shielding is placed over the insulation rather than between insulation and the conductor as corona strand shielding [described in paragraph 11a(1)(d)]. The principal functions of an insulation shield are:

1 To confine the dielectric field within the cable.

2 To obtain symmetrical radial distribution of voltage stress within the dielectric.

3 To protect the cable when subjected to induced potentials.

4 To limit radio interference.

5 To reduce the hazard of shock. (The shield must be grounded to make this effective.)

6 To provide a ground return in the event of cable failure.

(b) Electrical Stress Distribution. One of the most important reasons for shielding is to permit a predictable and uniform electrical stressing of the insulation. This is illustrated in figure 2-3. For example, a nonshielded high-voltage cable in a conduit will be in contact with the ground (the conduit) at some places, but will be separated from the conduit in other places. Figure 2-3 (item A) shows that the air space above the cable acts as an added insulation. The conductor voltage will stress the cable insulation to a higher volt per mil gradient where the cable touches the conduit than where air separates the cable insulation from ground. If a metallic shielding is placed over the insulation, the stress becomes even in all directions radially around the conductor. High and low stress points are eliminated as shown in figure 2-3 (item B).

(c) Corona Prevention. Shielding is also important in preventing corona (ionization) of air between the insulation and nearby ground. It is possible that the air in the region labeled "possible corona" in figure 2-3 (item A) could be voltage stressed to ionization.

(d) Insulation Shielding Construction.

1 **Semiconducting Nonmetallic Layer.** A semiconducting nonmetallic layer is used directly over the insulation of shielded power conductors to provide more intimate contact between the insulation and the metallic shield. It is at least 0.0025 inch thick and consists of carbon-black-filled cloth, rubber, neoprene, or extruded polyvinyl chloride.

2 **Metallic Shielding.** Shieldings are either metal, tape, braid, or wire. In general, rubber-covered cable with a synthetic jacket is shielded when manufactured for 3000 volts or more. Cables accessible to personnel should be shielded at any voltage above 2000 volts to reduce the shock hazard. Metallic tape shielding is generally 5 mils thick and is usually applied over the semiconducting nonmetallic tape.

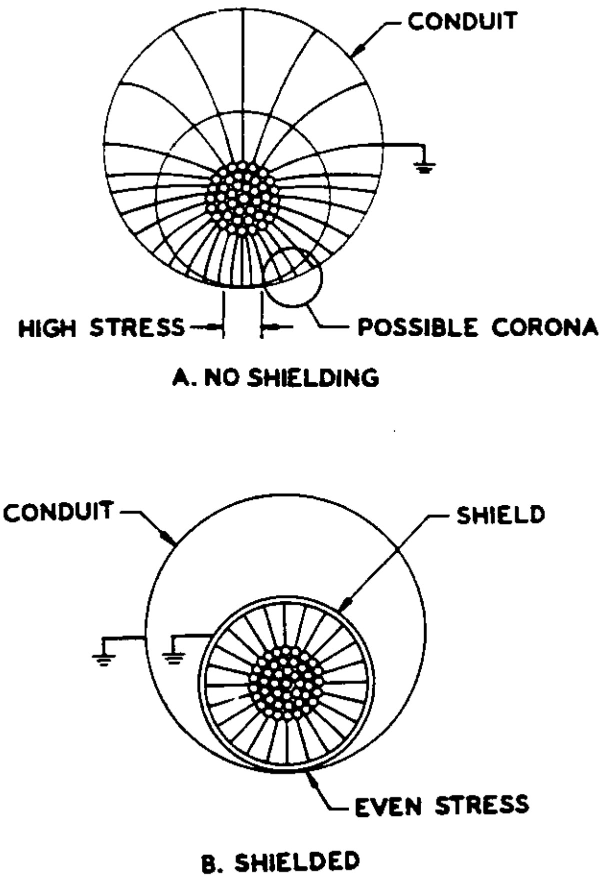


Figure 2-3. Electrical Stressing of Insulation in Shielded and Nonshielded Cables.

(4) Cable Jacket Covering.

(a) General. Wires and cables are generally subjected to varying amounts of abuse, depending upon how and where they are installed and their use. Cables buried directly in the ground must resist moisture, chemical action, and abrasion. Overhead transmission lines must have a high tensile strength and must withstand the continuous exposure to the weather. Generally, except for overhead transmission lines, wires or cables are protected by some form of covering called a jacket.

(b) Jacket Materials. The jacket over the insulation is basically made from four different materials: natural and synthetic fibers, rubber, thermoplastic, and metal. These materials are used in conjunction with bedding and filling tapes. The cable jacket should not be regarded as insulation.

1 Fibrous Covers. Cotton, linen, silk, rayon, and jute are types of fibrous covers. They are used for outer covering where the wire or cable is not exposed to heavy mechanical injury. Cotton braid provides a relatively low cost, flexible covering with good strength. It is used as a protective covering for the wire or cable that would normally be used in a comparatively dry location. Various materials such as compounds of petroleum asphalt and derivatives of animal and vegetable fats are used for saturating and finishing cotton braids, to provide moisture resistance and nonflammability. A final coating of paraffin gives a nontacky finish that aids in pulling the cable into conduit.

2 Rubber and Rubberlike Coverings.

a Natural Rubber. This jacket is made of vulcanized natural rubber compounds. It is adversely affected by oils, ozone, and sunlight. Most natural rubber compounds are being replaced by neoprene.

b Synthetic Rubber. Synthetic rubber is a good heavy duty jacket material for aerial, duct, and buried installations. Two types of jackets commonly used are Buna-N and neoprene. The use of Buna-N has been limited to special service conditions, such as extremely low temperature areas or where maximum oil resistance is desired. Its strength and flexibility at low temperatures and its oil resistance are excellent. Neoprene has excellent weather resistance, good aging, and good mechanical properties. Black neoprene, properly compounded, will not deteriorate on long exposure to sunlight and weather or in wet locations, such as underground. Heavy duty portable cords and cables are now made almost exclusively with neoprene-compounded sheaths. Neoprene has replaced cotton braids and other fibrous coverings on high grade cables.

3 Thermoplastic Covers. Thermoplastic compounds are widely used as cable jackets. Thermoplastic compounds common to cable manufacturing offer excellent resistance to many destructive chemicals and oils. This advantage, along with good moisture resistance, makes them suitable as a good nonmetallic jacket in damp locations and for aerial installations.

4 Metallic Jacket. A metallic jacket provides mechanical protection to the cable and may also function as a current return path. Metallic jackets are fabricated from lead, aluminum, steel, or a combination of these.

a Lead Jacket. A lead jacket is used with varnished-cambric and paper insulated cable for mechanical protection and to prevent moisture from entering and damaging the insulation. Lead is particularly suited for this purpose since it may be applied in long, continuous lengths. It forms a flexible covering, allowing the cable to be bent easily during handling and installation. Because of its expense, lead jackets have been replaced by other materials.

b Aluminum Jacket. Aluminum jackets are lightweight and are capable of withstanding high internal pressures. Aluminum is not as ductile a metal as lead and therefore requires a larger bending radius. A thermoplastic or neoprene jacket is applied over an aluminum jacket to eliminate corrosion, particularly on the type used for direct burial.

(5) Cable Armor.

(a) General. Steel armor provides a tough protective covering for cables. The armor thickness and the method of applying the steel armor about the cable depend upon the circumstances under which the cable is to be used.

(b) Types. There are four types of steel armor in use: flat metal tape, interlocked metal tape, steel wire, and wire braid or basket weave. The metallic armor is usually applied over a jute bedding. A fibrous covering, or jacket, is applied over the armor for good mechanical protection and strength. Because of the magnetic properties of steel armor, it is not feasible for use on a single conductor cable.

(6) Concentric Neutral Conductor.

(a) General. The concentric neutral conductor is a comparatively new type of cable construction. It has become popular with utility companies for underground distribution. Figure 2-4 shows a cutaway section of a concentric neutral cable.

(b) Neutral Size. As a general rule, the total area of the outside neutral wires equals the cross-sectional area of the main conductor. This is done because these wires provide the neutral or ground return for the cable.

(c) Outer Jacket. Some concentric neutral cables have a jacket over the neutral conductors. This jacket protects the cable during installation and prevents chemical attack. It also helps to prevent deterioration of the semiconducting bedding tapes used between the neutral conductors and the cable insulation.

b. Receiving and Handling of Power Cables.

(1) Inspection. Power cable should be inspected and tested before placing it in a trench, pulling it into a duct, or fastening it to an overhead messenger cable. Broken reels indicate that the reel has received rough handling. The cable should be inspected for cuts, gouges, flat spots, or any other defects or injury to the cable sheath. If the cable appears to have been damaged, it shall be thoroughly inspected and replaced or repaired if the damage will in any way affect its performance. Cable is normally shipped with the ends sealed. If a seal is broken, it should be repaired immediately. Unprotected cable ends are susceptible to moisture penetration, dirt, and other contamination. Protect any exposed cable ends by placing a moisture-seal, vinyl mastic pad over the end of the cable and overwrapping it with several layers of vinyl tape (e. g. Scotch 2200 and 33+). Seal the cable ends before installing the cable in a trench, and make sure the seals remain intact until the cable is spliced or terminated.

(2) Tests. Cable should be tested while on the reel and also after installation in a conduit system, open trench, or on an overhead supporting system. Tests shall be made for opens, shorts, and insulation resistance in accordance with the procedures in Chapter 5, Maintenance Procedures. The insulation resistance must equal or exceed the standard as shown in Chapter 3, Standards and Tolerances. The shield and armor shall be tested for continuity. Tests after installation shall be made after all splices are made and all terminations are completed, but prior to energizing or placing the cable in service.

12. CONTROL CABLE CONSTRUCTION, EXTERIOR TYPE.

a. General. Exterior types of multiconductor control cables generally have conductors ranging in size from No. 19 AWG to No. 8 AWG with 600-volt polyethylene insulation, a moisture resistant compound core, an overall shield or armor, and a polyethylene outer jacket. Conductors are made of solid annealed copper, except for

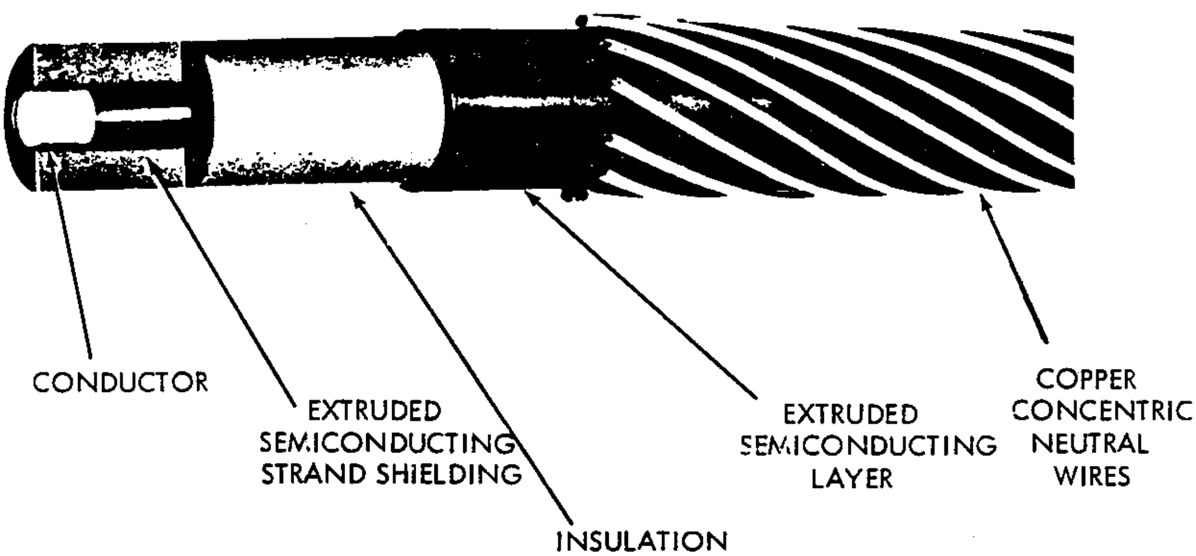


Figure 2-4. Cutaway Showing Construction of a Concentric Neutral Cable.

No. 14 AWG and larger, which are made of stranded copper. Shielding of pairs in some cables consists of aluminum foil cemented to mylar plastic foil with an uninsulated, tinned, copper drain wire. The drain wire is one size smaller than the conductor pair wire. Pair shielding in some cables consists of an uncoated copper-woven braid. Overall cable shielding is usually helically wound aluminum. The cable armor may be copper, bronze, or copper-clad stainless steel and is helically wound or corrugated.

b. Types. Six types of exterior electrical control cable are manufactured in accordance with FAA-E-2042.

(1) **Type 1A** — Paired conductor cable, each pair individually shielded, and with an overall jacket for duct or overhead installation.

(2) **Type 1B** — Same as type 1A, but including armor for direct earth burial.

(3) **Type 2A** — Unpaired conductor cable with an overall shield and jacket for duct or overhead installation.

(4) **Type 2B** — Unpaired conductor cable with armor and an overall jacket for direct earth burial.

(5) **Type 3A** — Mixed groups of pairs and/or multiconductor construction with shielding as specified, and with an overall jacket for duct or overhead installation.

(6) **Type 3B** — Same as type 3A, but with armor for direct earth burial.

c. Control Cable Conductor Color Coding.

(1) **Unpaired Conductors.** Table 2-1 shows a color code sequence for cables containing from 1 to 21 conductors.

TABLE 2-1. COLOR CODE FOR UNPAIRED CONTROL CABLE (From IPCEA S-61-402)

Conductor Number	Background or Base Color	Tracer Color
1	Black	None
2	White	None
3	Red	None
4	Green	None
5	Orange	None
6	Blue	None
7	White	Black
8	Red	Black
9	Green	Black
10	Orange	Black
11	Blue	Black
12	Black	White
13	Red	White
14	Green	White
15	Blue	White
16	Black	Red
17	White	Red
18	Orange	Red
19	Blue	Red
20	Red	Green
21	Orange	Green

(2) **Paired Conductors.** Table 2-2 shows a color code sequence for 1 to 25 cable pairs. Each pair is distinguished from every other pair by the colors of the insulations for each pair in a 25-pair group. Colored or imprinted binders distinguish individual 25-pair groups, from each other.

TABLE 2-2. COLOR CODE FOR CONTROL AND TELEPHONE-TYPE CABLE PAIRS (From IPCEA S-56-434).

Pair No.	Tip	Ring
1	White	Blue
2	White	Orange
3	White	Green
4	White	Brown
5	White	Slate
6	Red	Blue
7	Red	Orange
8	Red	Green
9	Red	Brown

TABLE 2-2. — Continued

Pair No.	Tip	Ring
10	Red	Slate
11	Black	Blue
12	Black	Orange
13	Black	Green
14	Black	Brown
15	Black	Slate
16	Yellow	Blue
17	Yellow	Orange
18	Yellow	Green
19	Yellow	Brown
20	Yellow	Slate
21	Violet	Blue
22	Violet	Orange
23	Violet	Green
24	Violet	Brown
25	Violet	Slate

d. Receiving and Handling of Exterior Control Cable.

(1) **Inspection.** Control cable should be inspected while still on the reel and then again as it is unreeled for installation.

(2) **Tests.** The cable should be tested for continuity, shorts, and insulation resistance while on the reel, before being energized or placed into service, and after terminating and splicing. Continuity of shields and armor should also be tested. After installation exterior control cables must comply with the following requirements in accordance with FAA-C-1391:

11 pair cable or less — All conductors must be acceptable.
12 to 25 pair cable — All conductors must be acceptable, except 1.
Over 25 pair cable — All conductors must be acceptable, except 2.

13. CONTROL CABLE CONSTRUCTION, INTERIOR TYPE.

a. One Shielded Pair. In accordance with FAA-E-2003 the conductors are generally made of No. 20 AWG stranded and tinned copper that is covered with thermoplastic insulation. They also contain a polyester and aluminum foil pair shield with an uninsulated stranded and tinned copper drain wire. The outer jacket is polyvinyl chloride, with a ripcord underneath to facilitate jacket removal. Insulation colors are solid black and white.

b. Multipaired. In accordance with FAA-E-2004 conductors are generally made of No. 22 AWG stranded copper with thermoplastic insulation and a thermoplastic jacket. Individual pair shielding is polyester and aluminum foil with an uninsulated stranded copper drain wire. All shields are covered with a polyester tape. The cable jacket is polyvinyl chloride, with a ripcord underneath to facilitate jacket removal.

c. Color Coding. Table 2-2 shows the color coding for interior control cable.

d. Receiving and Handling of Interior Control Cable. Inspections and tests are the same as required for exterior control cables. Postinstallation requirements for acceptable conductors are the same as for exterior control cables as shown in paragraph 12d(2).

14. TELEPHONE-TYPE CABLE, EXTERIOR TYPE.

a. General. Exterior, telephone-type multipaired cable, fabricated in accordance with FAA-E-2072, has No. 22 AWG or No. 19 AWG solid-copper conductors with propylene or polyethylene insulation. The cable has a moisture-resistant, compound filled core and a polyethylene or modified poyethylene outer jacket.

b. Classification.

(1) **Types.** Multipair telephone-type cables are classified by two types.

(a) **Type I** — 6 to 100 pair cable for duct or overhead installation.

(b) **Type II** — Same as type I, except with a composite shield and armor for direct earth burial.

(2) **Paired Conductor and Group Binder Color Coding.**

(a) **Paired Conductor Color Coding.** Both types I and II cable are furnished with the pairs color coded as shown by table 2-2. In cables having 25 pairs or less, the twisted pairs are assembled in layers to form a cylindrical core. Adjacent layers are cabled in the same direction or in opposite directions. Fillers, if used, are polyethylene.

(b) Group Binder Color Coding. Both types of telephone cables are furnished with the group binders color coded as shown by table 2-3. In cables having more than 25 pairs, the twisted pairs are grouped, each group, being bound by moisture-resisting threads or tape. Each group contains not more than 25 pairs. When desired for layup reasons, the basic 25-pair groups may be divided into two or more subgroups called units. Each unit in a particular 25-pair group are bound with threads or tapes of the colors indicated for its particular 25-pair count. The pair count, indicated by the colors of insulation, is consecutive (from 1 to 25, as given in table 2-3) through the units in a group. The binders are colored or imprinted to indicate the sequence of groups for pair identification. Binders made of threads consist of not less than three ends of each color, arranged as color bands. Binder tapes may be colored or they may be imprinted with the unit number and the names of the colors.

TABLE 2-3. COLOR CODE FOR CONDUCTOR GROUP BINDERS IN TELEPHONE-TYPE CABLE (From IPCEA S-56-434).

Group No.	Color of Binders	Group Pair Count
1	White-Blue	1-25
2	White-Orange	26-50
3	White-Green	51-75
4	White-Brown	76-100
5	White-Slate	101-125
6	Red-Blue	126-150
7	Red-Orange	151-175
8	Red-Green	176-200
9	Red-Brown	201-225
10	Red-Slate	226-250
11	Black-Blue	251-275
12	Black-Orange	276-300
13	Black-Green	301-325
14	Black-Brown	326-350
15	Black-Slate	351-375
16	Yellow-Blue	376-400

(c) Cable Shield. Type I cable has an overall aluminum tape or corrugated shield.

(d) Cable Armor. Type II cable has an overall armor of copper, bronze, or copper-clad stainless steel. The armor is taped or corrugated, and also serves as the overall cable shield.

c. Receiving and Handling of Telephone-Type Cable. Inspections and tests are the same as required for exterior control cables. Postinstallation requirements for acceptable conductors are the same as for exterior control cables, as shown in paragraph 12d(2).

15. COAXIAL CABLE.

a. Construction. All solid-dielectric or gas-filled dielectric coaxial cables have a solid, bare-copper center conductor. Some types of solid-dielectric cables have two bare-copper center conductors separated from each other by dielectric material. The cable dielectric material may be solid plastic, or it may be made of plastic in the form of beads, discs, foam, or a spiral. The dielectric separates the inner conductor(s) from the outer conductor. The outer conductor may be made of a bare, tinned, or silver coated copper braid, or may be made of corrugated copper or brass. The armor may be in the form of steel, copper, or bronze tape. The outer jacket is usually made of polyvinyl chloride or other thermoplastic. Gas-filled dielectric coaxial cable has its center conductor separated from the corrugated, or smooth, solid outer conductor by plastic discs. Air may be used as the dielectric, but the cable will carry approximately five times the radio frequency power when filled with low-pressure nitrogen gas.

b. Receiving and Handling of Coaxial Cable. Solid dielectric and gas-filled coaxial cable should be inspected for damage before installation. Gas-filled cable, which is normally shipped under pressure, should include with it information showing the date, pressure, and the ambient temperature when filled with dry nitrogen gas. If this pressure deviates more than 1 psig (.07kg/sqcm) from the value when the cable was shipped, then the cable should be pressure tested in accordance with Chapter 5, Maintenance Procedures. This type cable should be installed while still under pressure with all fittings in place. Both solid-dielectric and gas-filled cables should be tested for continuity, shorts, and dielectric resistance both before and after cable installation. These tests should be accomplished in accordance with Chapter 5, Maintenance Procedures.

Section 2. CABLE FAULT DETECTION — LOCATION AND TESTING

16. GENERAL.

Cables as a rule do not suddenly fail, except from severe mechanical or lightning damage. Deterioration from age alone is a very slow process. Most often a cable receives some gradual damage that hastens the process; e.g., damage from termite activity, rodents, micro-organisms, soil chemicals, and temperature effects (contraction and expansion). The migration of moisture into cable insulation accounts for most cable failures. When the insulation is punctured in power cables, moisture enters the damaged region, creating current leakage paths. At first only a small leakage current flows, but this current creates heat, and heat tends to char the insulation. This process may continue for weeks or even months before the leakage becomes great enough to make the cable unserviceable. Testing the quality of cable insulation may disclose an impending fault before complete failure occurs. However, if a cable fails, prompt location of the fault depends upon knowledge of the cable system and understanding the equipment and procedures for fault location.

17. CABLE MAINTENANCE.

The most feasible, economical, and easiest way to avoid damage due to cable faults is to prevent these occurrences by effective protection and maintenance methods. This requires periodic testing and inspection as well as the maintenance of records. The reduced risk of nonscheduled outages of airway facilities fully justifies the occasional scheduled outages of these facilities required for cable tests.

a. Analysis of Cable Records. By keeping a record and comparing the readings each time a cable is tested, an indication is given when a cable starts deteriorating rapidly or when cable failure is imminent. If the insulation resistance between conductors or between conductors and ground remains constant, it indicates that the cable condition is unchanged. Any appreciable drop in insulation resistance may indicate that the insulation or dielectric is deteriorating rapidly, and it may be necessary to repair or replace the cable. If the readings are erratic, possibly low in wet weather and high in dry weather, it indicates a moisture leak into the cable, and trouble can be expected.

b. Tests. All cables should be tested regularly and whenever defects are suspected. Chapter 4 of this handbook requires that periodic inspections and tests be made at least every three years. Regional maintenance practices may require cable tests more frequently than every three years.

c. Visual Inspection. While underground cable cannot be completely inspected, much can be learned from walking the route of the cable. Look for excavations, washouts, rodent activity, plowing or planting, recently installed stakes or posts, or any other evidence of possible cable damage. Examine all cable ends and potheads for faulty sealing, discoloration, or other evidence of heating or arcing. In the case of an overhead cable, the entire cable route should be walked and closely inspected. This inspection should be performed in the early spring, in the fall, and whenever there is a possibility that the cable or supporting structure may have been damaged, particularly when the overhead cable run is exposed to icing, high winds, or heavy rains. Any defects found should be promptly repaired.

d. Cable Load and Voltage Loss.

(1) General. The size of cable that is installed is determined when the system is designed. However, changes in equipment or the addition of new equipment may increase the load. Therefore, the load current must be measured periodically and when new equipment is installed to determine if the current-carrying capacity, termed ampacity, of a cable is adequate. If the ampacity of a cable is exceeded, excessive power is expended in the cable in the form of heat. The heating effects in turn can damage or wholly break down the insulation.

(2) Ampacity. Two physical factors of a cable generally determine its ampacity. The prime factor is the cross-sectional area of the conductor; the second factor is the heat dissipation. The larger the cross-sectional area of a conductor, the larger its ampacity. A conductor in free air has a greater ampacity for any given wire size than the same size conductor in a buried cable or any confined space where there is no ventilation. A higher ambient temperature also impedes the heat dissipation of any conductor. The National Electrical Code contains tables establishing the maximum allowable ampacities for any wire size under various ambient temperatures. A cable may be checked for overload by measuring the current in its conductors with a clamp-on ammeter. The measured current of any conductor should never exceed the maximum allowable ampacity for the wire size at the ambient temperature. Wire or cable temperature can be found by placing a thermometer on the conductor insulation surface. The thermometer bulb may be held in contact with the conductor insulation with electrical tape.

(3) Voltage Drop.

(a) Allowable Voltage Drop. In addition to supplying power without overloading the conductors, a power distribution system (whether private, municipal, or government owned) must deliver within-tolerance voltages to the facilities. Even a seemingly small voltage drop can greatly reduce equipment performance. A 1-percent voltage drop to an incandescent lamp produces about a 3-percent decrease in light output; a 10-percent drop decreases the light output about 30-percent. Some electronic equipment is even more adversely affected by low voltage. For this reason, FAA-owned power cables between the power source and facility electrical service are usually sized not only for the load imposed but also with a voltage drop under 1-percent on low-voltage circuits (120V, 240V, 480V, etc.) and under 5-percent on high-voltage circuits (2400V, 4160V, etc.)

(b) Voltage Drop Measurement. Checking the voltage drop of a cable is simply a matter of measuring the voltage applied to the cable, and measuring the output voltage at the load end of the cable. These measurements should be taken either by the same meter or by two similarly calibrated meters, to avoid the error that would otherwise be introduced by a variation in meter calibrations. For low-voltage circuits, the voltage drop should not exceed 1-percent of the applied voltage.

(4) Line Resistance.

(a) Whenever an excessive voltage drop occurs on a cable, the line resistance is an immediate concern. The following equation gives the resistance of a conductor.

$$R = KL/CM$$

where R = the ohms resistance of a single conductor

K = resistivity of conductor (CM-ohms/ft). (K = 12 for copper circuit loaded at more than 50% of allowable ampacity; K = 11 for copper circuit loaded less than 50%; K = 18 for aluminum).

L = length of the single conductor in feet

CM = circular mil area of the conductor

(b) Since the resistance of a conductor is directly proportional to its length and inversely proportional to its circular mil area, it is possible that a long cable run may have an excessive voltage drop even though the conductor size is adequate for the load current. If this is the case, the voltage drop may be brought within tolerance by using a larger conductor, thereby reducing the resistance of the run.

(5) Conductor Size Calculations.

(a) Calculations. The size of copper wire (of a cable pair) required to carry a given current any distance, with a given drop in voltage, can be determined by using table 2-4 and the following equation, based on Ohm's law.

$$A = LI2K/E$$

where E = drop in circuit voltage (volts)

L = one-way length of circuit (feet)

A = cross-sectional area of conductor (circular mils)

K = 12 for copper, 18 for aluminum

I = current in conductor (amperes)

(b) Example No. 1. Two-Wire DC or Single-Phase AC Circuits: (inductance negligible). Determine the voltage drop of a cable having a 100-foot run (paired

TABLE 2-4. STANDARD ANNEALED UNCOATED COPPER CONDUCTOR RESISTANCE

Gage	Diameter in Mils	Circular Mil (cmil)	Ohms per 1000 FEET at 77° F (25° C)
0000	460	211,600	0.0509
000	409.6	167,800	0.0642
00	364.8	133,100	0.0811
0	324.9	105,600	0.102
1	289.3	83,690	0.129
2	257.6	66,360	0.162
3	229.4	52,620	0.205
4	204.3	41,740	0.259
6	162.0	26,240	0.410
8	128.5	16,510	0.6404
10	101.9	10,380	1.018
12	80.81	6,530	1.62
14	64.08	4,110	2.57
16	50.82	2,580	4.10
18	40.30	1,620	6.51
19	35.89	1,290	8.21
20	31.96	1,020	10.30
22	25.35	640	16.50
24	20.10	404	26.20

NOTE 1. For each degree fahrenheit above or below 77° F, increase or decrease "ohms per 1000 feet" by 0.00385 times the value given in table 2-4.

NOTE 2. Resistivity of hard drawn copper is approximately 2.5% higher than for annealed copper.

conductors) of No. 14 AWG copper wire (cmil area 4110), 12-ampere load, with 120-volt input, as follows:

$$E = \frac{LI2K}{A}$$

$$= \frac{100 \times 12 \times 2 \times 12}{4110}$$

$$= 7.01V$$

In this example and all other examples in this section, inductance is negligible for 60Hz circuits with conductors less than 300 MCM. This calculation is for cables having good insulation. If there are defects in the insulation, which often exists in old cable, an additional loss in power will exist that cannot be readily calculated. However, this power loss can usually be measured with a wattmeter.

(c) **Example No. 2.** Two-Wire Circuit Conductor Size Calculations. In Example No. 1, the voltage drop of the cable exceeded the tolerance of 1 percent of the applied voltage. To determine what size conductor is required to deliver the voltage within tolerance (1.2 volts), use the following calculation (100-foot cable run of paired copper conductors, 12-ampere load, 120-volt input):

$$A = \frac{LI2K}{E} = \frac{100 \times 12 \times 2 \times 12}{1.2} = 24{,}000 \text{ cmil}$$

Since the conductor cross-section area must be at least 24,000 circular mils, table 2-4 shows that No. 6 AWG conductors would be required.

(d) Example No. 3. Three-Wire, Three-Phase Circuit (Inductance Negligible). Determine the circuit voltage drop of three existing No. 2 copper conductors (66,360 cmil) in a 150-foot cable, which is to serve a 95-ampere balanced load as follows:

$$E = \frac{LI2K}{A} \times 0.866$$

$$= \frac{150 \times 95 \times 2 \times 12}{66{,}360} \times 0.866$$

$$= 4.46V$$

Minimum conductor sizes are calculated as in example No. 2, and are 164,423 and 142,500 cmils for 208-volt and 240-volt systems respectively. From table 2-4, it is determined that No. 3/0 conductors can be used for both systems to limit the voltage drop to 1 percent or less.

(e) Example No. 4. Four-Wire, Three-Phase Balanced Circuit (Inductance Negligible) With Unbalanced Single-Phase Loads. Determine the voltage drop in an existing 150-foot, four-wire cable of No. 2 (66,360 cmil) copper conductors with a 95-ampere, 208-volt balanced three-phase load. In addition, a 10-ampere single-phase load and a 15-ampere single-phase load are connected between separate phase conductors and the neutral. The remaining phase conductor has no single-phase load connected. Example No. 3 calculations show that the 95-ampere load alone will cause a 4.46-volt drop in the outside conductors. The 10-ampere and 15-ampere loads will cause additional voltage drops in two of the phase conductors. Because the 15-ampere load additional voltage drop is largest,

$$E = \frac{LI2K}{A} \times 0.5$$

$$= \frac{150 \times 15 \times 2 \times 12}{66{,}360} \times 0.5$$

$$= 0.41V$$

The particular phase conductor then would have a combined voltage drop of 4.87 volts (4.46 + 0.41), which exceeds the 1 percent allowable voltage drop of 2.08 volts. In practice, the phase conductors generally would be replaced with conductors of the same size. The size is determined by the requirements of the more heavily loaded phase conductor as follows:

$$A = \frac{LI2K}{E}$$

$$= \frac{150 \times 110 \times 2 \times 12}{2.08}$$

$$= 190{,}385 \text{ cmil}$$

From table 2-4, it is determined that No. 4/0 conductors (211,600 cmil) should be used. The calculations applied in this example also may be used if a single-phase load is connected between one or three of the phase conductors to neutral. Conductor size for the three-phase conductors would be determined by the required size of the phase conductor carrying the largest current. The calculations used in this example may be applied if a single-phase load is connected between each of two of the phase conductors to neutral of a four-wire delta system. The size of the two phase conductors would be sized for minimum voltage drop, based on the combined three-phase current and largest single-phase current requirements. In practice, the third phase conductor, carrying only three-phase current, would be smaller than those installed to carry the combined three-phase and single-phase currents.

e. Insulation and Dielectric Resistance Testing.

(1) General. The insulating properties of a cable deteriorate steadily from the effects of aging, and more rapidly with the entry of moisture. Thus the measurement of insulation resistance or dielectric resistance (coaxial cables) provides a reliable indicator of the presence of such conditions and of general insulation performance. Insulation or dielectric resistance is the resistance to the flow of direct current through or over the surface of the insulating material. Cables are tested by measuring the resistance between conductors, and between each conductor and ground. In multiconductor cables, such as control and telephone-type cables, the resistance is measured between unpaired conductors, between conductors in the same pair, or between the conductors of different pairs. In coaxial cables the dielectric resistance is measured between the inner and outer conductors. For a new cable, or one that is in very good condition, all of these resistances should measure in megohms, as shown in chapter 3, Standards and Tolerances.

(2) **Test Instruments.** To perform insulation resistance tests requires a much higher voltage than that furnished by the internal battery of the usual ohmmeter. In addition, the measuring range of a suitable test instrument should extend into the megohms. Such resistance testing instruments must be nondestructive to the cable insulation or dielectric material being tested.

(a) **Low-Voltage Insulation-Resistance Test Equipment.** Several manufacturers produce nondestructive test equipment that measures the resistance of the insulation between two conductors. This type of instrument may be handcranked or motor driven so that its internal dc generator can supply 250, 500, or 1000 volts between the conductors. The insulation resistance is read directly from the instrument dial.

(b) **High-Voltage Insulation-Resistance Test Equipment.** The high-voltage resistance tester is designed to test cable insulation resistance and dielectric resistance at dc voltages between 2000 and 15000 volts. This tester is a nondestructive type designed to apply across the test specimen a voltage which varies inversely with leakage current.

CAUTION: This instrument contains dangerous and possibly lethal voltages. For personal safetv of the operator and protection of this instrument, the ground lead provided must be attached securely to a driven ground rod or water pipe. Before any connections are made and before the instrument is energized, make sure the instrument is properly grounded. The operator of the instrument should wear insulated rubber gloves whenever making any adjustments or corrections on this instrument and never operate it while alone. Before using this type of instrument, consult the manufacturer's instruction book for detailed operating instructions.

18. CABLE FAULT LOCATION.

a. **General.** Cable faults are resistance paths through the insulation paralleled by a gap or flashover path. The resistance path may vary from near zero, as for a shorted circuit, to very high values in the order of megohms. No one fault-locating method is capable of "pinpointing" the exact location of the fault under the many variable conditions encountered in the field with respect to cable types, installations, and environmental factors.

b. **Cable Fault Classifications.** Cable faults consist of three general types: grounded, short, and open circuits. The technician must first determine the type of fault involved, in order to decide which fault-location method to use. The types of faults and the tests for these faults are as follows:

(1) **Grounded Circuit.** This fault is a conduction path from a conductor to ground or to some conducting body serving as ground (a metallic cable shield or armor). In checking for a grounded conductor, the ohmmeter is connected between each conductor and ground while the far end of the cable is open. A zero or near zero ohms reading indicates a direct or low-resistance ground. A higher resistance ground is also possible. An ungrounded conductor gives a reading approaching infinity. Deteriorating insulation will cause insulation resistance to become progressively lower.

(2) **Short Circuit.** This fault is a conduction path between two conductors. In paired cables a variaton of this fault, termed a cross, is actually a short between two conductors not of the same pair. In checking for a short circuit between conductors, the ohmmeter is connected between the two conductors with the far end of the cable open. A zero or low ohms reading indicates a short. Nonshorted conductors give a reading approaching infinity.

(3) **Open.** This fault is a break in a conductor. The continuity of a conductor is determined by grounding the conductor at the far end and then connecting the ohmmeter between the conductor and ground at the near end. A near infinite resistance reading indicates an open circuit. If the conductor is continuous, a zero or low resistance reading is obtained.

c. **Fault Location Methods.** Terminal and tracer methods are used in locating cable faults.

(1) **Terminal Methods.** Terminal methods involve measuring and comparing an electrical characteristic of the faulted cable with unfaulted conditions in terms of distance to the fault. Terminal measurements use either a Murray Loop resistance bridge or an ac form of Wheatstone bridge to measure cable capacitance. More recently, pulse reflection (pulse echo or radar) equipment is being used to determine the distance to the fault.

(2) **Tracer Methods.** The tracer methods involve placing an electrical signal on the faulted conductor, tracing along the cable length, and then detecting it by a change in signal at the fault. Fault tracing detectors may provide either audible or visual indications.

d. Terminal Method Test Instruments. Various cable fault location instruments are used by maintenance personnel. Several of the most commonly used instruments are as follows:

(1) **Wheatstone Bridge.** The Wheatstone bridge is a very precise instrument for measuring electrical resistance. The ohmmeter is sufficiently accurate for most resistance measurements and for determining if a circuit is open, shorted, or grounded. However, when a more precise resistance measurement is required such as for cable fault location, a test instrument such as a Wheatstone bridge must be used. Before using any Wheatstone bridge, consult the manufacturer's instruction book for the detailed operating instructions.

(2) **Capacitance Bridge.** Sometimes the location of a cable fault can be determined from measurements of capacitance between the conductors of a cable. Capacitance is most commonly measured by a capacitance bridge, because these instruments are accurate and convenient. The simplest form of an ac bridge resembles the dc Wheatstone bridge from which it evolved. Manufacturers employ many variations of the ac bridge for capacitance measurement. Therefore, always consult the manufacturer's instruction book for the detailed operating instructions of a particular instrument.

(3) **Murray Loop Bridge.** The dc Murray loop bridge consists of a Wheatstone bridge, which uses a continuous loop of cable to form two arms of the bridge circuit. Any test instrument that can be externally connected to operate as a Wheatstone bridge usually can be connected to operate as a Murray Loop bridge. The Murray Loop circuit is used for locating low resistance faults that cannot be located by other nondestructive test equipment.

(4) **Time-Domain Reflectometer.** This type of instrument operates by impressing short-duration direct current pulses on the faulty cable and permits observation of reflected pulse shape, amplitude and polarity. This reflected pulse results from a change in cable impedance caused by the open, short, or resistive fault. The instrument contains an oscilloscope to observe the transmitted and reflected pulses. The oscilloscope screen is calibrated so that an actual fault can be located within a few feet. This instrument is replacing most other fault-locating equipment.

e. Tracer Method Test Instruments.

(1) **Impulse Generator (Thumper).** The impulse generator uses a high dc voltage applied to an internal capacitor, which can be charged to an adjustable value. The cable under test is connected in series with the sphere gap and capacitor. When the voltage in the gap reaches the preset value, the capacitor discharges across the gap and a pulse of energy with a very steep wave front is transmitted along the cable length to flash across the fault with a loud, audible report to reveal its exact location. If the fault is located in a duct, the report can be heard at adjacent openings. Buried cable faults can sometimes be heard above the ground, or the shock wave felt by the feet. In very deep installations, particularly in the presence of traffic noises, a pickup coil with a suitable indicating device, or earphones, may be used.

CAUTION: Because of the lethal voltages used in impulse type testers, operators of such devices must observe all applicable safety precautions. Remember, too, that the charge induced in other conductors within a cable may be high enough to be lethal also. Therefore, during tests, adjacent conductors should be disconnected and the exposed ends insulated.

(2) **Audio Frequency Fault Locator.** A number of low-voltage audio frequency or tone-tracing devices are used for locating faults in cable. They generally consist of audio-frequency transmitters and detectors that can rec-

ognize changes in signal level at the fault. Such devices are effective on faults that are near zero in resistance. High resistance faults can result in unreliable indications as the signal can "carry over" beyond the fault.

f. Terminal Fault Location Methods.

(1) General. Resistance and capacitance measuring instruments are used to determine the type and location of a cable fault without destroying or damaging the cable. The use of these instruments, with the exception of the time-domain reflectometer, requires that calculations be made to determine the distance from either or both ends of the cable to the fault.

(2) Shorted Pair Fault. A short circuit between two conductors is illustrated in figure 2-5. The distance D_f to the fault can be calculated if the resistance is known. Since this determination is based on the ohms per foot of the conductors, the resistance must be measured very accurately using a Wheatstone bridge.

(a) Distance to Fault Calculation. After measuring the resistance between points A and B, the distance to the fault, D_f, may be calculated from the following relationships:

$$\frac{R_t}{1000} = \frac{R_L}{L}$$

where R_t = ohms per 1000 feet (table 2-4)

R_L = loop resistance in ohms (measured)

L = total length of wire within the loop, in feet.

D_f, which is ½ L, can be obtained by solving the above equation for the length, L, and dividing the result by 2.

$$D_f = \frac{1000\ R_L}{2\ R_t}$$

1 **Example:** A short has developed across two No. 19 conductors in a cable. The loop resistance is measured on a Wheatstone bridge and found to be 12.16 ohms. Determine the distance to the fault:

2 **Solution:**

R_t = 8.21 for No. 19 wire from table 2-4

$$D_f = \frac{1000\ R_L}{2\ R_t}$$

$$= \frac{1000 \times 12.16}{2 \times 8.21}$$

$$= \frac{12160}{16.42}$$

$$= 740.6 \text{ feet}$$

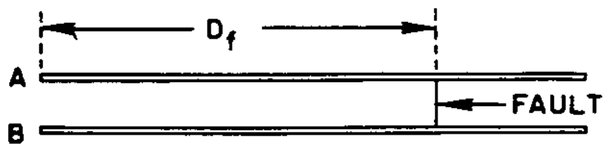


Figure 2-5. Resistance Loop Formed by Shorted Conductors.

(b) Calculated Versus Actual Distance to Fault. The actual distance along the cable route might differ from the calculated value by several feet. For example, FAA crews bury a slack cable loop approximately 3 feet in length at each end of a buried cable run and at all buried cable splices. Also, a loop is made where a buried cable is brought above ground. Since 3 feet of the calculated distance is taken up in each loop, this length should be allowed for when measuring the distance to the fault. The accuracy of the equation used for calculating purposes may also be affected by temperature. In table 2-4 the table resistance, R_t, is established at 77° F (25° C). Thus, if the temperature of the conductor is substantially higher than this temperature, its resistance is higher. The table resistance may be temperature-corrected by the following equation:

$$R_{tc} = R_t \pm (0.00385 \times R_t \times T_{df})$$

where R_{tc} = temperature-corrected table resistance

R_t = table 2-4 resistance

T_{df} = temperature difference between 77° F (25° C) and the conductor temperature

NOTE: If the ambient cable temperature is greatly different than 77° F (25° C) then R_{tc} should be calculated and used in the equation in place of R_t.

1 **Example:** The resistance loop method is to be used to find the distance to a cable short. The cable temperature is measured and found to be 28° F. For No. 19 conductors, determine the value of R_{tc}.

2 **Solution:**

$$R_{tc} = R_t \pm (0.00385 \times R_t \times T_{df})$$

$$= 8.21 - (0.00385 \times 8.21 \times 49)$$

$$= 8.21 - (1.55)$$

$$= 6.66 \text{ ohms}$$

(3) **Low Resistance Ground Fault.** Figure 2-6 shows the circuit for the Murray Loop test, which can be used for locating low resistance grounds. The faulty conductor and a good conductor of the same cable are joined at the far end by a jumper wire, and a Wheatstone bridge is connected at the near end to measure the total loop resistance. The bridge is then connected to form the Murray Loop circuit as shown in figure 2-6. The galvanometer, battery, and two resistors R_d and R_m are components of the bridge instrument. When the bridge is balanced, the following equation is applicable:

$$R_1 = \frac{R\,(R_m)}{R_m + R_d}$$

where R_1 = resistance to the fault from measuring terminal, in ohms

R = measure loop resistance, in ohms

R_d = sum of the Murray Loop instrument decade dial settings

R_m = multiplier or ratio dial setting of the Murray Loop instrument

After the resistance to the fault, R_1, has been determined, the distance to the fault, D_f, may be found by dividing 1000 R_1 by R_t, the ohms per 1000 feet of the loop conductor (from table 2-4). This relationship may be expressed as:

$$D_f = \frac{1000\,R_1}{R_t}$$

1 **Example:** An initial ohmmeter check indicates that one conductor of a two-wire cable (No. 8 wire) is shorted to the cable shield. The good conductor and the faulted conductor are then shorted at the far end, and the resulting loop resistance as measured with a Wheatstone bridge is found to be 4.094 ohms. Using the Murray Loop circuit of figure 2-6, the bridge is balanced when R_m = 100 and R_d = 3526. Based on the above values, the calculated distance to the fault can be determined.

2 **Solution:**

$$R_1 = \frac{R\,(R_m)}{R_m + R_d}$$

$$= \frac{4.094\,(100)}{100 + 3526}$$

$$= \frac{409.4}{3626}$$

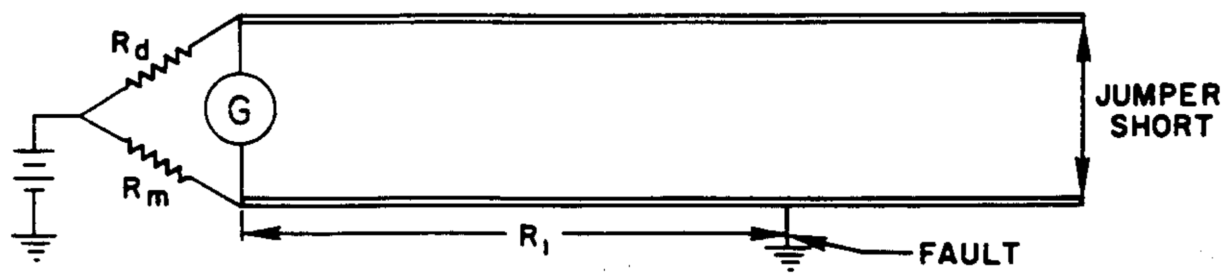


Figure 2-6. Murray Loop.

$= 0.1129$ ohms

$$D_f = \frac{1000\,R_t}{R_t\,(\text{ohms}/1000\text{ ft})}$$

$$= \frac{1000\,(0.1129)}{0.6404}$$

$$= \frac{112.8}{0.6404}$$

$= 176.3$ feet

(4) **Open-Conductor Fault.** An open conductor, as shown in figure 2-7, results most frequently from mechanical damage such as that encountered when underground cable is cut in trenching or digging operations. Open conductors can be located using the capacitance bridge fault location method.

(a) **Capacitance Bridge Fault Location Method.** The capacitance bridge fault location method can be used where one conductor is open and is free of low resistance grounds and is not shorted. The basis of this method is that the generally constant capacitance between parallel conductors of a cable is directly proportional to the length of the cable. Thus, the length of a faulted section can be calculated by comparing the capacitance with that of a continuous section of known length.

(b) **Distance to Fault Calculations.** First, open the conductors of the faulted pair at both ends of the line, as indicated in figure 2-7. Then, using a capacitance bridge, measure the capacitance between the conductors at both ends of the line. The distance to the fault, D_f, from a reference end of the line can be calculated from the following relationship.

$$D_f = \frac{DC_f}{C_t}$$

where D_f = distance in feet to the fault from the reference end of the line.

C_f = capacitance in picofarads (pF) measured between the conductors at the reference end of the line.

C_2 = capacitance in pF measured between the conductors at the far end of the line

$C_t = C_f + C_2$ (total line capacitance in pF)

D = total length of line in feet

1 **Example:** An open circuit has developed in a 1000-foot cable. The capacitance measured from the generator end is 3.5 pF, and from the load end is 7.8 pF. The distance to the fault from the generator end can be found as follows.

2 **Solution:**

$$D_f = \frac{DC_f}{C_t}$$

$$= \frac{1000\,(3.5)}{3.5 + 7.8}$$

$$= \frac{3500}{11.3}$$

$= 309.7$ feet

(5) **Open-Conductor Fault Calculation Variation.** In this variation, the length of the good line section must be known. See figure 2-8. Here the capacitance C_f is measured between the faulted conductor and the cable shield. C_t is measured between the good conductor and

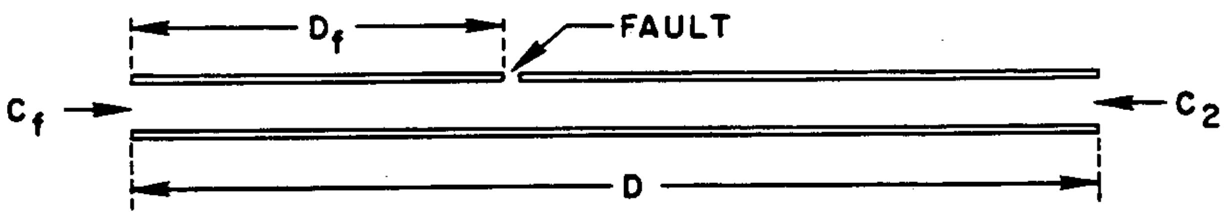


Figure 2-7. Open Conductor and Capacitance Between Conductors.

the shield. This variation has the advantage that both capacitance measurements can be taken from the same end of the line. The equation of subparagraph (4)(b) above is used to calculate the distance to the fault.

g. Tracer Fault Location Method.

(1) Impulse Method of Fault Location.

(a) General. The impulse generator, sometimes referred to as a "fault locator", may be used to locate grounds, shorts, and open circuits. This equipment tends to strike an arc at the fault, which can cause further breakdown of the cable. Therefore, in a marginal cable this equipment may develop additional faults. Never apply the impulse generator to any cable with less than 5kV insulation.

(b) Impulse Generator Theory of Operation. The impulse generator uses pulses of energy released by a capacitor at 2- or 3-second intervals, to lower the resistance of a fault so it can be more easily located. The voltages produced are lethal, so proper safety precautions must be taken. Induced voltage in other conductors within the cable are also dangerous. Therefore, these conductors should be insulated. Before connecting any impulse equipment to a cable, disconnect both ends of the cable from all regular terminations. Ground the impulse generator with the terminal provided on the case. This is necessary to prevent the impulse generator from becoming dangerously charged from electrostatic action. Assure that the impulse generator is operating properly, by testing it on a short length of cable or by placing the output clips about three-eighths inch apart and observing the flashover. When the cable has more than two conductors, disconnect and insulate both ends of all conductors except the one to be checked. Connect the impulse generator as shown in figures 2-9, 2-10, 2-11, or 2-12. Turn on the impulse generator and adjust for impulses to occur generally between 10,000 and 15,000 volts in accordance with manufacturer's instructions.

1 Grounded Conductor Fault. Figure 2-9 shows the connections to be used with a single conductor shorted to its grounded metal shielding. The high voltage lead of the impulse generator is connected to the faulted conductor, and the ground lead of the impulse generator is connected to the shield. The shield must also be connected to a good earth-ground system. If an unshielded cable is in a grounded armor, metal conduit or underground metal duct and a ground fault develops, connect the impulse generator as in figure 2-10, using the armor, conduit or metal duct in lieu of the shield.

2 Shorted Conductors Fault. If a short circuit develops between two conductors of a circuit, connect the instrument as shown in figure 2-11. Here the leads of the impulse generator are connected to the shorted pair. If the shorted conductors are armored or are in a metallic conduit or duct, the connections should be made as in figure 2-11, with the high voltage lead connected to either of the faulted conductors and the ground lead of the impulse generator also connected to the grounded armor, conduit, or duct.

3 Open Conductor Fault. Figure 2-12 shows the connections to be used for a single conductor that has a break at some point. The high voltage lead of the impulse generator is connected to one end of the faulted conductor, and the ground lead is connected to ground. The other end of the faulted conductor is also connected to ground.

(c) Impulse Detection Theory of Operation. Proceed over the cable route using the pickup coil, amplifier, and headset to monitor the signal radiated from

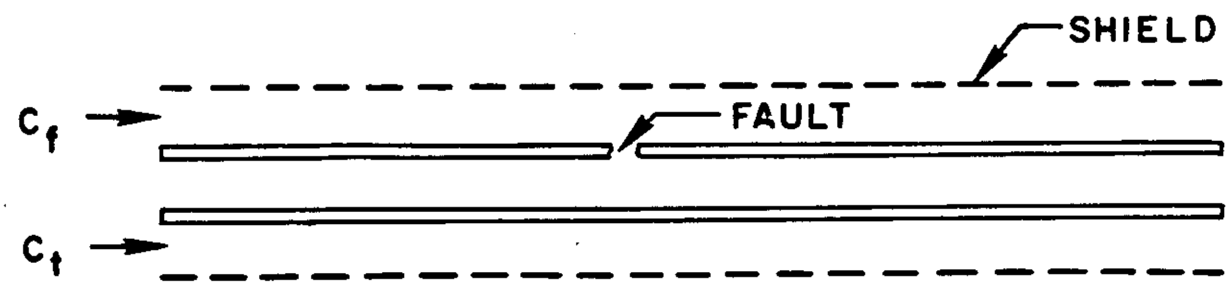


Figure 2-8. Open Conductor and Capacitances From Conductors to Shield.

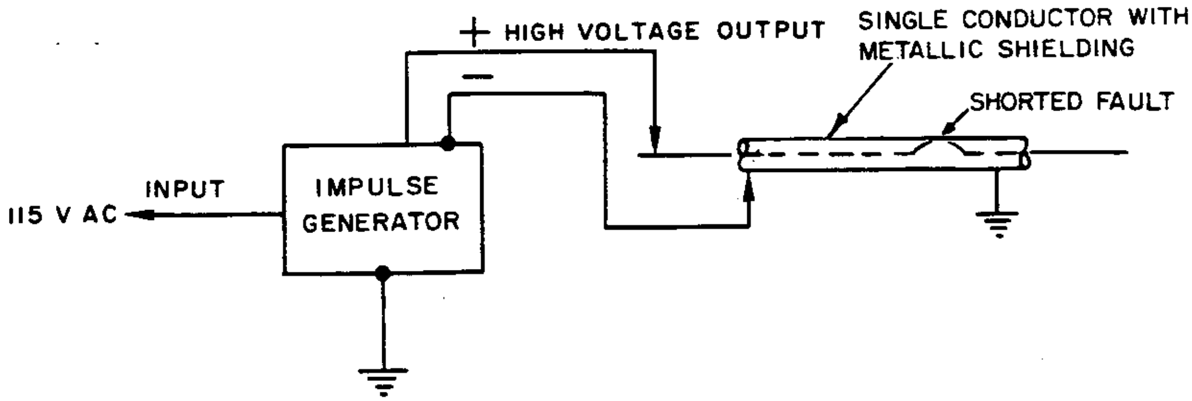


Figure 2-9. Cable With Conductor Shorted to Metal Shield.

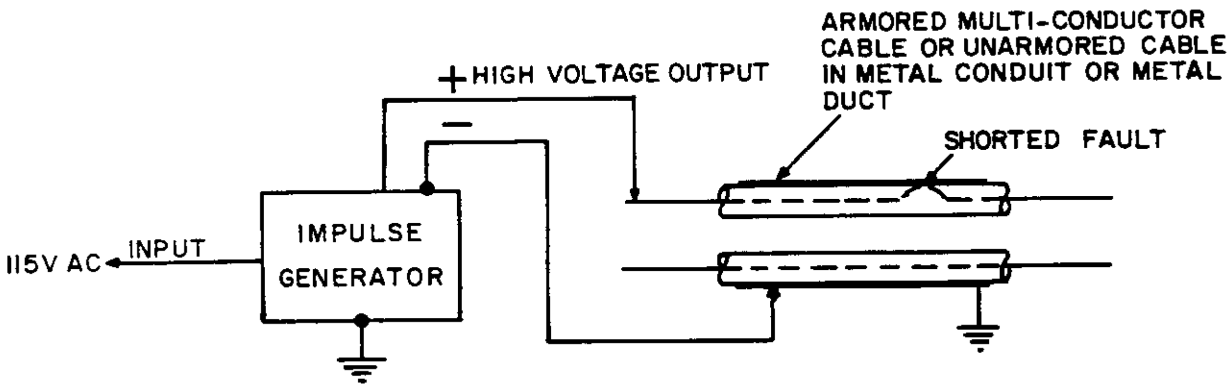


Figure 2-10. Cable With Conductor Shorted to Armor, Conduit or Duct.

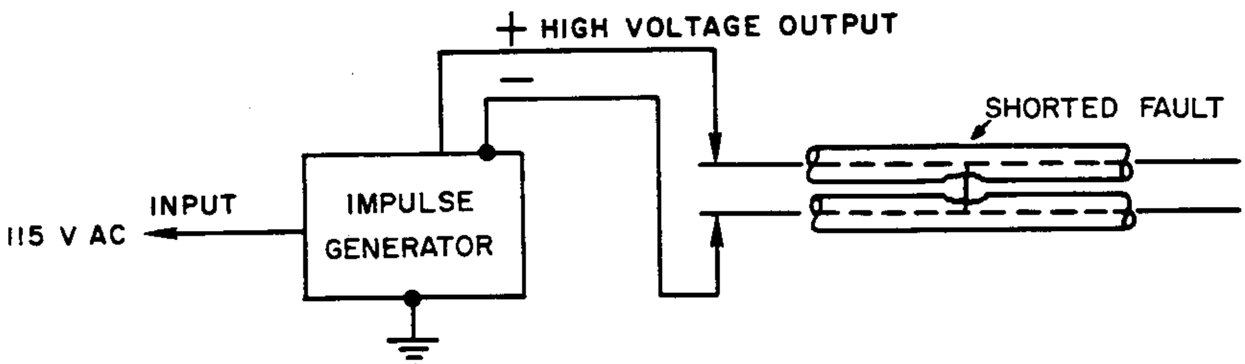


Figure 2-11. Two Shorted Conductors in Cable.

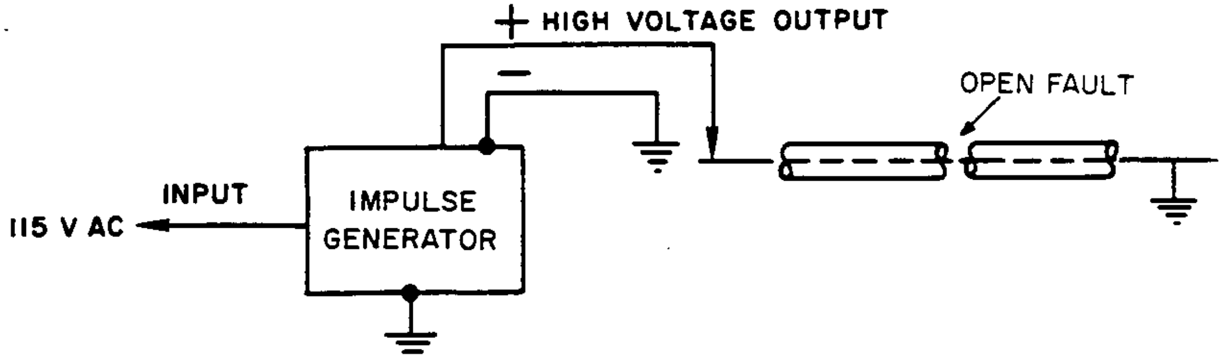


Figure 2-12. Open Conductor in Cable.

the cable. At first the impulses from only the impulse generator will be received. Turn the volume of the amplifier to the lowest value at which a signal can be heard and locate the position where it is loudest. This will be directly over the cable. Flashover will produce a different sound, such as a series of clicks that differ from those heard from the fault locator impulses, a series of dull thuds when occurring underground, or a loud audible report when in the open. The latter two signals can often be heard without the aid of an amplifier. On some faults, such as a conductor flashing over to a metallic armor or shield, the noise under ordinary conditions can be heard from buried cable up to several feet away from the fault.

1 **Difficult Faults.** If no fault is located, retrace the cable route, keeping the volume of the amplifier as low as possible. Listen carefully for any change in signal.

a **Signal Strength Change.** If a change in signal strength is heard, however slight, mark the location. Then continue to operate the impulse generator for about one-half hour, because continued flashover may change the nature of the fault into one more easily found. Return to the marked location and try again for a change in signal, which could indicate the location of the fault.

b **Unchanged Signal Strength.** If no change in signal is heard, use the sound detector probe. Apply it to the ground every 6 feet (1.82 meters) and listen for the characteristic thump of a fault flashover. If no change in signal is noted over the entire cable route, connect both the faulted conductor and a good conductor together on each end of the cable run. This may result in a signal change, which indicates a fault. If necessary, connect the impulse generator on the other end of the cable and repeat the checks.

2 **Spurious Signals.** Where the faulted cable lies near other cables, these adjoining cables may pick up the signal and rebroadcast it, thereby misleading the equipment operator. This results in the signal being heard beyond the fault. This situation can be overcome by short-circuiting the other individual conductors to cause the false signals to cancel.

3 **Signal Change Interpretations.** Signal changes heard from a run of cable when using the pickup coil and earphone will fall in the following categories:

Signal Heard	Fault Location
Sharp falling of volume.	A few inches to a few feet back from change in signal. Actual location may be found where signal is loudest.
Gradual reduction of volume.	Ten to twenty feet back from first noticeable change in signal.
Sudden increase in one spot.	Exact location.
Gradual loss of signal throughout length of run	Indicates that cable has deteriorated over a wide area.

4 Cable Deterioration.

a Insulation. If the signal indicates that the insulation has deteriorated, test the insulation resistance.

b Cable Short. If the signal is weak or inaudible in the receivers, the conductors may be shorted together within th cable. In this case, operate the impulse generator for an additional half hour. This may temporarily remove the short, allowing a signal to be detected in the receiver. If this is not successful, current may be passed through the conductors for a short time in an effort to burn them apart.

(2) Sensitive Voltmeter Method of Fault Location.

(a) **General.** Ground faults can be located with a fault locator and a sensitive voltmeter that has a high resistance input.

(b) **Theory of Operation.** When an impulse generator is connected to a faulty buried cable, the voltage difference from the fault back through the earth to the fault locator can be measured by a voltmeter. This potential difference is detected by two metal probes connected to the voltmeter that are inserted into the earth 6 to 10 feet (1.82 to 3.19 meters) apart. Because these are dc impulses, the meter will read in either of two directions, depending on the polarity of the meter leads. The voltage difference can only be detected in the vicinity of the cable run, and the strongest meter deflection is that detected with the probes located in a line parallel to the cable.

(c) **Pulse Search.** The probes should be moved along the cable route away from the impulse generator, at intervals of 20 feet (6.1 meters) in systematic progression (maintaining the same relative position of the probes). A wide deflection of the needle occurs near the fault location. The meter deflection will gradually become smaller as the probes are moved along the cable route away from the fault. As the fault is approached, the meter deflection will increase again in the same direction. When the fault is passed, the direction of the voltmeter deflection will be reversed. Then, by moving the probes at closer intervals, the fault may be located exactly.

(d) **Effects of Soil Moisture.** Since this fault-locating method depends upon the measurement of ground currents, it is highly subject to the effects of ground moisture and soil composition. It may work well during a moist season and fail during a dry season. It may also work or fail to work in various geographical locations.

(3) **Audio Method of Tracer Fault Location.** The "audio method" of fault location uses a signal source applied to telephone and control cables and a detection device that gives an audible indication of the fault location. The received audio signal can be used to operate a meter for a visual indication. The audio method has several advantages. First, it may be used to locate any type of fault. Second, because it employs no high voltage, it may be used on any type of cable and is safe for operating personnel.

Section 3. CABLE INSTALLATION PRACTICES

19. CABLE INSTALLATION.

a. **General.** Power and control cables are installed both overhead and underground. This section deals only with underground installations. For overhead installations, refer to the latest edition of Order 6950.18, Maintenance of Electrical Distribution Systems.

b. **Cable Removal.**

(1) **Cable in Underground Duct System.** When replacing a cable in an underground duct system, attach a rope to the far end and pull out the old cable. The new cable may then be pulled in, using the same rope. If the old cable cannot be removed in one piece, cut the cable at handholes or manholes and remove it in separate sections. If the existing cable must be reused, withdraw the cable using a rope or pull wire. The rope or wire can be installed with the aid of a steel tape. When using steel tapes, care must be taken so that the steel tape does not damage the conductors.

(2) **Direct-Earth-Burial (DEB) Cable.** DEB cable should be excavated and removed from the ground if a

new cable is to be installed in its place. If replacement cable is not to be installed, old DEB cable may be abandoned with all conductors, shields, and armor grounded on both ends.

c. New Underground Cable Installation.

(1) General. Underground cables are more susceptible to damage during installation than above-ground cables or open conductors. Most underground cable failures can usually be attributed to damage incurred during installation. Where cables are direct-buried without ducts in a joint right-of-way with communication cables, a failure could mean abandonment of the cable run. For these reasons, the installation crew should be well trained and should exercise extreme care at all times. Many cable failures are caused by damage inflicted as a result of carelessly dragging cables or running over them with heavy equipment. If at all possible, cables should be reeled out along the side of the trench from moving reels or carefully laid in the trench from stationary reels. When cables are pulled into ducts or open trenches, pulling eyes or other attachments should not be connected directly to the conductor. Instead, a pulling grip placed directly over the cable should be used. Regardless of the type of cable system being installed, whether direct burial or in duct, burial practices are essentially the same with respect to installation equipment, trench profiles, and depth of burial. Cables installed underground, whether direct burial or in duct, are subject to movement due to heat variations or earth upheaval caused by frost. It is therefore essential that sufficient cable slack is allowed at all risers and terminations to permit cable movement. Occasionally, cable failures occur at the terminal ends, and the additional slack is helpful in making repairs and may avoid the need for a future splice at the end of the cable.

(2) Trenching.

(a) DEB Cable or Duct Trench Minimum Depths.

1 Direct earth burial cables should be a minimum of 24 inches (60.96cm) below the finished grade when on airport or government controlled property and 36 inches (91.44cm) below the finished grade when off airport or government controlled property. Cables should not be direct buried under paved areas, roadways, railroad tracks or ditches.

2 Direct earth burial ducts should be installed so that the top of all ducts are at least 18 inches (45.72cm) below the finished grade. Direct earth burial ducts, except rigid steel conduit, should not be installed under paved areas, roadways, railroad tracks or ditches.

3 Concrete encased duct or rigid steel conduit should be installed so that the top of the concrete envelope or conduit is not less than 18 inches (45.72cm) below the bottom of the paving where installed under runways, taxiways and other paved areas and not less than 18 inches (45.72cm) below the finished grade when installed in unpaved areas.

4 When the cable routing is under railroad tracks, the cable should be in rigid steel conduit or concrete encased duct with the top of the duct at a minimum depth of 42 inches (106.68cm) below the base of the rail.

5 Where rock excavation is encountered, the rock should be removed to at least 3 inches (7.62cm) below the required cable depth.

(b) Minimum Width. Trench widths should be at least 6 inches (15.24cm). When a given spacing is required between cables, several narrow, parallel trenches — 6 inches (15.24cm) minimum — may be excavated instead of one wide trench.

(c) Separation Between Direct-Earth-Burial Cables. Backfill materials separating cables should be firmly tamped in place. Direct earth burial cable should be separated as follows:

1 Power cables, of the same circuit, may be laid together in the trench without separation, except as noted below. Series lighting cables may be considered of the same circuit.

2 Power cables, of the same or different circuits of less than 600 volts, may be laid together in the same trench without separation.

3 All power cables, 5,000 volts and below, must be separated from all control, telephone and coaxial type cables by a minimum of 6 inches (15.24cm).

4 Power cable, of more than 5,000 volts, shall be separated from all other cables by a minimum of 12 inches (30.48cm).

5 Control, telephone, and coaxial cables may be laid in the trench without separation from each other.

(3) **Cable Installation in Conduit or Duct.**

(a) **Underground Duct.** When obstructions, such as runways, roads, or parking ramps, are in the logical route of the cable trench, it is necessary to install the cable in duct. For the most part, the ducts used at FAA sites are nometallic and are usually 4 inches (10.16 cm) in diameter.

(b) **Conduit or Duct Risers.** If a conduit is to be terminated above ground, a transition from nonmetallic to metal conduit should be made at the bend of the conduit before it rises from the ground. If this is done, care should be taken to assure that all three conductors of a three-phase circuit are contained in the same metallic conduit. Unless all three conductors are run in the same metallic conduit, excessive conduit heating results, with consequent damage to the cable insulation.

(4) **Cable Pulling.**

(a) **General.** There are many methods used in cable pulling such as block and tackle, chain hoist, winches, and on short pulls of cable, by hand. It is important to pull the cable directly in line to reduce friction. Care should be taken to keep the cables free from kinks, and pulls should be made directly from reels where possible. Do not subject conductors or cables to a strain or bend them beyond their natural lay. Avoid forcing the cables around bends. Rough handling of cables causes damage. Care exercised when installing any cable is well worthwhile to insure a trouble-free installation. Table 2-5 shows the maximum allowable pulling tension for non-armored cable when using a dynamometer or rope.

(b) **DEB Cable Pulling Into Trench.**

1 **Unreeling.** DEB cable should be unreeled from a moving reel and placed in the open trench or placed along the trench and then carefully laid into the trench. The cable may be damaged if it is pulled into the trench or dragged along the trench bottom.

2 **Installation Splicing.** Whenever possible, cable shall be run in one piece, without splices, from connection to connection. When cable cutting is required, cable ends shall be immediately sealed against * moisture with moisture-seal, vinyl mastic pads and vinyl tape. Splicing shall be done in accordance with * instructions in chapter 5 of this handbook.

3 **Cable Bends.** Bends of a radius less than 8 times the diameter for rubber and plastic-covered cable and 12 times the diameter for metallic-armored cable shall not be made. Cable that has been kinked shall be repaired before being installed.

4 **Cable Loop.** A cable loop of approximately 3 feet (0.91m) shall be left on each end of cable runs, on one side of splices, and at all points where cable connections are brought above ground. The slack loop shall be installed with the same minimum depth requirements as the cable run. Loops shall have no bends with an inner radius less than 12 times the outside diameter of the cable. Where the cable is brought above ground, additional slack cable shall be left to make the required connections.

(c) **Pulling Cable in Duct or Conduit.**

1 **Duct Cleaning.** Before pulling cable into ducts or conduit, assure that the duct is open, continuous, and clear of debris. A tight-fitting swab or brush can be used to clean the duct, and a mandrel of wood or metal slightly smaller in diameter than the duct can be pulled through the duct to remove foreign material.

2 **Spare Duct Pull Wires.** A minimum size No. 10 AWG coppper-clad steel pull wire should be installed in each spare duct.

3 **Cable End Sealing.** The ends of all cables should be sealed with moisture-seal tape before pulling the cable into duct and should be left so sealed until ready for termination. The cable must be installed in such a way as to avoid stretching of the conductor or damage to the insulation or the outer protective covering.

4 **Splices.** No splices shall be drawn inside the ducts.

5 **Pulling Lubricant.** If necessary to relieve strain on cable during pulling, a lubricant approved by Underwriter's Laboratories, Inc., should be used.

6 **Multiconductor Cable Unreeling.** All multiconductor control cables should be pulled off the reels in the same direction during installation in ducts. This will

TABLE 2-5. ALLOWABLE NON-ARMORED CABLE PULLING TENSION USING DYNAMOMETER OR ROPE.

Cable			Tension	Maximum Rope Diameter in inches			
Quantity	Conductors per Cable	Size or Type	Maximum Pounds	Cotton Rope	Manila Rope	Dacron Rope	Nylon Rope
2	1	#8 Solid	275	3/16			
3	1	#8 Solid	367	1/4	3/16		
4	1	#8 Solid	550		1/4		
2	1	#6 Stranded	420	1/4	3/16		
3	1	#6 Stranded	630	5/16	1/4		
4	1	#6 Stranded	840	3/8		3/16	
1	2	#8 Stranded	305	1/4			
1	3	#8 Stranded	395	1/4			
1	4	#8 Stranded	585		1/4		
1	2	#6 Stranded	455	1/4	3/16		
1	3	#6 Stranded	685	5/16			
1	4	#6 Stranded	880	3/8''	5/16	3/16	
1	6	#12 Stranded	315	1/4			
1	12	#12 Stranded	630	5/16	1/4		
1	12 Pairs	#19 Solid	230	3/16			
1	25 Pairs	#19 Solid	541		1/4		
1	50 Pairs	#19 Solid	1061	7/16			3/16
1	100 Pairs	#19 Solid	2000		15/32	5/16	
1		RG — 11A/U	85	3/16			
1		RG — 213/U	125	3/16			
1		RG — 214/U	145	3/16			
1		RG — 216/U	135	3/16			
1		RG — 217/U	250		1/4		
1		RG — 218/U	800	7/16			

NOTE: For maximum pulling tension of cables not listed, see manufacturers recommendations. Coaxial cables shown here have solid dielectric. See paragraph 19c(4) (e)2 for pulling tension of gas-filled coaxial cable.

facilitate matching of color-coded conductors and reduce difficulties in splicing.

7 **Pulling Through Manholes and Handholes.** The reels should be placed so that the cable will run in a smooth curve through the manhole opening to the duct without making a reverse bend.

8 **Hand or Winch Pulling.** The cable should be pulled by hand winch or power winch. The pulling-in

rope should be attached to cables. using cable grips designed for the job. Large cables. and other cables when length of run. curves. etc.. warrant. shall be lubricated with talc or with an approved cable lubricant.

(d) Cable Installed in Manholes and Handholes.

1 Power and Control Cables. Power and control cables should be installed in separate manholes or handholes wherever possible.

2 Control. Telephone-Type, and Coaxial Cables. Whenever control, telephone-type, or coaxial cables are in the same manhole or handhold with power cables, they should be installed on the opposite side of the manhole or handhole from the power cables. If this is not practicable, they should be separated * as far as possible from the power cables. The entire length of all controls cables within the manhole or handhole shall be fireproofed, using electric-arc and fireproofing materials such as Minnesota Mining and Manufacturing Company No. 77 tape. Per Occupational Safety and Health Administration (OSHA) guidelines, materials with the chance of freeing asbestos dust should not be used. *

3 Power, Control, Telephone-Type and Coaxial Cables. In no event will control. telephone-type. or coaxial cables be installed in the same duct with power cables.

4 Cables Installed on Racks. Where other support is not available. cables should be supported carefully on cable racks. All splices should be supported on cable racks so that movement of cable due to temperature changes will not strain the splices or cause the splice to slip from the racks.

5 Duct Assignment. In general. high voltage cables shall be assigned to the lower outside ducts and low voltage cables to the upper layers of ducts in the interior of a duct bank. Any given cable should be installed in the same duct position throughout its run whenever possible.

(e) Installation of Gas-Filled Coaxial Cable.

1 General. Coaxial gas-filled cable is received in the field under nitrogen gas pressure. This cable must be installed in one piece under pressure with fittings and seals kept securely in place at all times during cable handling and installation. The ambient temperature and pressure at the time the cable was filled with nitrogen and the date thereof should be furnished with the cable. Correction factors for nitrogen gas pressure for given temperature changes are listed in table 5-1.

2 Bending Radius and Pulling Tension. * Semirigid heliax. 7/8-inch (2.2cm) diameter. must not be subjected to a bending radius of less than 30 inches (76.20cm) during installation or less than a 20-inch (50.80cm) radius when secured in place. Further. the * maximum allowable pulling tension for this type cable is 750 pounds (340.5kg). If the pulling tension approaches the maximum allowable or if there is doubt as to the amount exerted. a dynamometer should be used to monitor the pulling tension. Utmost care should be exercised at all times to prevent kinking any part of the cable during installation. Care must be exercised so that the plastic jacket surrounding the cable is not damaged. since this jacket is provided for corrosion protection when the cable is buried in the earth. Refer to manufacturers specifications for pulling tension and minimum bending radius for other gas-filled cable * when pulling or securing in place.

20. TRENCH BACKFILL.

The trench should be backfilled as soon as possible after the cable or duct is placed in the trench and is tested. The cable must be protected from rocks and objects that might damage the insulation during backfilling. The first layer of backfill should be 3 inches (7.62cm) deep. loose measurement. and be either earth or sand containing no material aggregate particles that would be retained on a ¼-inch sieve. This layer should not be compacted. except as required for cable separation. The second layer should be 5 inches (12.7cm) deep. loose measurement. and should contain no particles that would be retained on a 1-inch (2.54cm) sieve. The remainder of the backfill should be excavated or imported material and should not contain stone or aggregate larger than 4 inches (10.16cm) maximum diameter. The third and subsequent layers of the backfill should not exceed 8 inches (20.32cm) in maximum depth. loose measurement. The second and subsequent layers should be thoroughly tamped and compacted to at least the density of the adjacent undisturbed soil. If necessary to obtain the desired compaction. the backfill material should be moistened or aerated as required. Trenches should not be excessively wet and should not contain pools of water during backfilling operations. The trench should be completely backfilled and tamped level with the adjacent surface. When sod is to be placed over the trench the backfilling should be stopped at a depth equal to the thickness of the sod to be used.

21. CABLE MARKERS.

The location of underground cable runs should be marked by 2 foot square concrete cable markers. The markers should be installed at intervals not to exceed 200 feet (60m), at all cable splices, and at points 1 foot (0.3m) before and 1 foot (0.3m) after each change in direction.

22. CABLE TERMINATIONS.

a. General. A cable termination performs two basic functions. One is to provide an end for the cable conductor, insulation, and insulation shield, which is grounded; the other is to provide a suitable means for connecting cable to electrical equipment. In addition, many times the termination performs the necessary function of sealing and physically protecting the cable end.

b. High-Voltage Termination Considerations. When a power cable is terminated and the insulation shield removed, an abrupt change results in the electric field surrounding the conductor. The result is a concentration of electrical stresses at the point where the shielding ends along the insulation surface. These nonuniform stress concentrations, as shown in figure 2-13, cause insulation breakdown and cable failure. To prevent failure, the cable must be terminated in such a manner that uniform stresses on the cable insulation are continued.

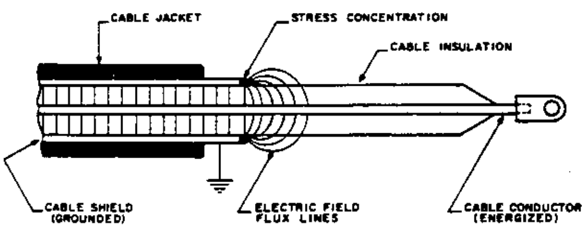


Figure 2-13. Stress Concentration In a Termination Without a Stress Cone.

c. Stress Relief Cone. The common method of relieving the stress at the end of the cable shield is to reinforce the cable by building up additional insulation in the form of a double cone. (See figure 2-14.) The cable shield is then extended to the peak of the cone (point A) by use of a semiconducting tape or braid. As can be seen in figure 2-14, there is now more insulation between the shield edge and the conductor. This added insulation called a "stress cone" not only reinforces the cable at the shield edge but also reduces the concentration of electrical stress. (The stress concentration is not completely eliminated but is reduced to the point where an electrical failure should not occur.)

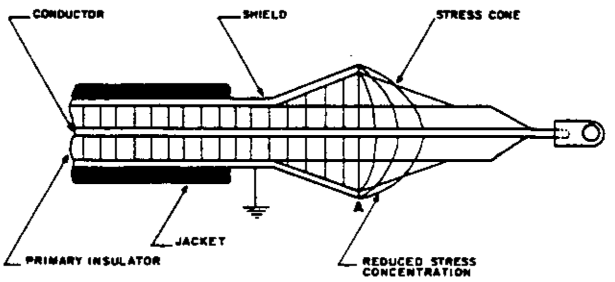


Figure 2-14. Stress Concentration In a Termination With a Stress Cone.

23. FUSE PROTECTION FOR HIGH VOLTAGE CABLE.

Enclosed fuse cutouts and oil fuse cutouts are overcurrent protection devices used to protect both overhead and underground lines.

a. Enclosed Fuse Cutout. Enclosed fuse cutouts provide an economical and reliable overcurrent protection and disconnecting means for distribution circuits and equipment. Fuse cutouts are available for practically all voltage and current normally used by FAA facilities. They may be indicating or nonindicating. The indicating type shows a blown fuse by dropout action of the fuse tube or by the fuse cutout door dropping open.

b. Oil Fuse Cutout. Oil fuse cutouts are completely metal enclosed and are available for circuits up to 300 amperes at 7500 volts. The fuse link in this cutout is submerged in oil, which acts as an arc extinguisher when the link blows. The oil fuse cutout is used mostly on indoor installations.

24. LIGHTNING ARRESTERS.

Lightning arresters are used to protect insulation from voltage surges caused by lightning disturbances and switching operations. The arrester selection depends on arrester location, circuit voltage, and the equipment to be protected. Normally, arresters are connected on the line side of disconnecting switches and fuses, on the outgoing overhead feeders of a substation, at terminals of underground and overhead lines, at termination points of control lines or cables, and on the primary side of all distribution transformers.

25. CATHODIC PROTECTION.

Cathodic protection is a method used to minimize corrosion of underground metallic structures associated with a facility. Cathodic protection also used to protect buried conductors, conduit, cable armor, and cable shielding whether bare or covered with a jacket or insulation. This method of corrosion protection uses one or more sacrificial anodes that are electrically connected to the metal to be protected. Several anodes may be required to protect the entire length of the metal, since protection afforded by an anode depends upon the soil resistivity immediately surrounding the anode. A sacrificial anode usually consists of a short magnesium rod with a length of insulated copper wire attached. The wire is soldered, brazed, or clamped to the metal to be protected. The protected metal becomes cathodic in relation to the buried anode when both are in contact with soil moisture. The anode, being more chemically active than the cathode material, reacts with the salts within the soil moisture to electrochemically create a current that minimizes corrosion of the cathode material. Without cathodic protection, ferrous metals in contact with soil moisture containing salts create a current that results in corrosion. This current causes the ions of the metal to go into solution with the soil moisture, causing the metal to corrode at a rate determined by the soil resistivity (salt content of the soil moisture). The opposition current created by the use of a sacrificial anode causes the ions of the anode to go into solution with the soil moisture thus protecting the cathode at the expense of the anode. The anode eventually wears away and must be replaced

26.-29. RESERVED.

CHAPTER 3. STANDARDS AND TOLERANCES

30. GENERAL.

a. This chapter prescribes the standards and tolerances for maintenance of electrical power and control cables, as defined and described in the latest edition of Order 6000.15, Maintenance of Airway Facilities. All key performance parameters and key inspection elements are identified by an arrow (→) placed to the left of the applicable item.

b. Standards and tolerances are given in this chapter for both new and old cables. For purposes of this order, cable is considered to be "new" from the time it is installed until its first annual performance tests. After the first annual tests the cable is considered "old."

c. The insulation resistances given in this chapter for "old" cables are average values only, and should not be used as a basis for cable replacement. Insulation deterioration depends upon so many variables such as the type of insulating compounds, moisture and chemical content of various soils, weather, air contamination, etc., that no specific insulation resistance values can be set as a criteria for replacement. Replacement decisions must be based on an analysis of test values taken over a period of time. A rapid decrease in insulation resistance indicates possible future breakdown and suggests a need for further investigation using the fault location equipment described in chapter 2.

CHAPTER 3. STANDARDS AND TOLERANCES

Parameter	Reference Paragraph	Standard	Tolerance/Limit	
			Initial	*Operating*
31. POWER CABLE TESTS.				
a. Power Cable, 600-Volt Insulation.	52b(1)			
(1) Conductor-to-conductor insulation resistance.				
→ (a) New cable		30MΩ min at 500V dc	Standard	Standard
(b) Old cable		10MΩ min at 500V dc	Standard	2MΩ min at 500V dc
(2) Conductor-to-ground insulation resistance.				

CHAPTER 3. STANDARDS AND TOLERANCES — Continued

Parameter	Reference Paragraph	Standard	Tolerance/Limit	
			Initial	Operating
(a) New cable		30MΩ min at 500V dc	Standard	Standard
(b) Old cable		10MΩ min at 500V dc	Standard	2MΩ min at 500V dc
b. Power Cable, 5kV Insulation.	52b(2)			
(1) Conductor-to-conductor insulation resistance.				
(a) New cable		50MΩ min at 10kV dc	Standard	Standard
(b) Old cable		10MΩ min at 10kV dc	Standard	2MΩ min at 10kV dc
(2) Conductor-to-ground insulation resistance.				
(a) New cable		50MΩ min at 10kV dc	Standard	Standard
(b) Old cable		10MΩ min at 10kV dc	Standard	2MΩ min at 10kV dc
c. Power Cable, 15 kV Insulation	52b(2)			
(1) Conductor-to-conductor insulation resistance				
(a) New cable		50MΩ min at 31kV dc	Standard	Standard
(b) Old cable		10MΩ min at 31kV dc	Standard	2MΩ min at 31kV dc

CHAPTER 3. STANDARDS AND TOLERANCES — Continued

Parameter	Reference Paragraph	Standard	Tolerance/Limit Initial	Tolerance/Limit Operating
(2) Conductor-to-ground insulation resistance				
(a) New cable		50MΩ min at 31kV dc	Standard	Standard
(b) Old cable		10MΩ min at 31kV dc	Standard	2MΩ min at 31kV dc
d. Approach Lighting System Series Loop Cable, 5kV Insulation.	52b(3)			
(1) Conductor-to-ground insulation resistance.				
(a) New cable		50MΩ min at 10kV dc	Standard	Standard
(b) Old cable		10MΩ min at 10kV dc	Standard	1MΩ min at 10kV dc
(2) Loop resistance, new and old cable.		Measured value not to exceed calculated value by more than 20%	Standard	Standard
32. FAA-OWNED CONTROL AND TELEPHONE-TYPE CABLE TESTS.				
a. Voice-Grade Circuits, operating at less than 100V AC or DC. (300V and 600V insulated)				

CHAPTER 3. STANDARDS AND TOLERANCES — Continued

Parameter	Reference Paragraph	Standard	Tolerance/Limit	
			Initial	Operating
(1) Conductor-to-conductor insulation resistance.				
(a) New cable	53c(2)	50MΩ min at 500V dc	Standard	Standard
(b) Old cable	Order 6000.22	20kΩ min at 500V dc	Standard	Standard
(2) Conductor-to-ground insulation resistance.				
(a) New cable	53c(2)	50MΩ min at 500V dc	Standard	Standard
(b) Old cable	Order 6000.22	10kΩ min at 500V dc	Standard	Standard
b. Monitoring and Signaling Circuits, AC or DC (300V and 600V insulated).	53c(2)			
(1) Conductor-to-conductor insulation resistance.				
(a) New cable		50MΩ min at 500V dc	Standard	Standard
(b) Old cable		2.5MΩ min at 500V dc	Standard	Standard
(2) Conductor-to-ground insulation resistance.				

CHAPTER 3. STANDARDS AND TOLERANCES — Continued

Parameter	Reference Paragraph	Standard	Tolerance/Limit Initial	Tolerance/Limit Operating
(a) New cable		50MΩ min at 500V dc	Standard	Standard
(b) Old cable		2.5MΩ min at 500V dc	Standard	Standard
33. COAXIAL CABLE TESTS.				
a. Gas-Filled Dielectric Cable.				
(1) Inner-to-outer conductor dielectric resistance, new and old cable.	54b(4)	Near infinite resistance at 3kV for 3 minutes (with connectors attached)	Standard	Standard
(2) Nitrogen gas pressure check, new and old cable.	54b(3)	No measurable loss of pressure	Standard	Standard
b. Solid Dielectric Cable (Inner-to-outer conductor dielectric resistance, new and old cable).	54b(4)	50MΩ min at 500V dc (with connectors attached)	Standard	3MΩ min at 500V dc (with connectors attached)
34.-39. RESERVED.				

Section 1. PERFORMANCE CHECKS — Continued

Performance Checks	Reference Paragraph	
	Standards & Tolerances	Maintenance Procedure
(b) Old cable	31b(1)(b) or 31c(1)(b)	52b(2)
(2) Measure conductor-to-ground insulation resistance.		
(a) New cable	31b(2)(a) or 31c(2)(a)	52b(2)
(b) Old cable	31b(2)(b) or 31c(2)(b)	52b(2)
c. ALS (Approach Lighting System) Series Loop Cable, 5kV Insulation.		
(1) Measure conductor-to-ground insulation resistance.		
(a) New cable	31d(1)(a)	52b(3)
(b) Old cable	31d(1)(b)	52b(3)
(2) Measure loop resistance, new or old cable.	31d(2)	52b(3)
d. FAA-Owned Control and Telephone-Type Cables, Paired or Unpaired.		
(1) Voice-Grade Circuits, Less Than 100V AC or DC.		
(a) Measure conductor-to-conductor insulation resistance.		
1 New cable	32a(1)(a)	53c(2)
2 Old cable	32a(1)(b)	53c(2)
(b) Measure conductor-to-ground insulation resistance.		

Section 1. PERFORMANCE CHECKS — Continued

Performance Checks	*Reference Paragraph*	
	Standards & Tolerances	*Maintenance Procedure*
1 New cable	32a(2)(a)	53c(2)
2 Old cable	32a(2)(b)	53c(2)
(2) Monitoring and Signaling Circuits, AC or DC		
(a) Measure conductor-to-conductor insulation resistance.		
1 New cable	32b(1)(a)	53c(2)
2 Old cable	32b(1)(b)	53c(2)
(b) Measure conductor-to-ground insulation resistance.		
1 New cable	32b(2)(a)	53c(2)
2 Old cable	32b(2)(b)	53c(2)
e. Coaxial Cable, Video and Triggering.		
(1) Measure inner conductor to outer conductor dielectric resistance.		
(a) Gas-filled dielectric.	33a(1)	54b(4)
(b) Solid dielectric.	33b	54b(4)
(2) Check nitrogen gas pressure, gas-filled dielectric.	33a(2)	54b(3)

Section 2. OTHER MAINTENANCE TASKS

Maintenance Tasks	Reference Paragraph: Standards & Tolerances	Reference Paragraph: Maintenance Procedure
42. SEMIANNUALLY.		
During early spring and in the fall, perform the following tasks on overhead cables.		
a. Inspect for damage to cables or to cable support system.	N/A	56b(1)
b. Inspect for potential cable or cable support damage caused by changes in terrain.	N/A	56b(1)
c. Inspect for adequate clearance.	N/A	56b(1)
43. ANNUALLY.		
Perform the following tasks on underground cables.		
a. Inspect cable route for damage due to changes in terrain and for evidence of current leakage or physical damage.	N/A	57
b. Inspect cable markers.	N/A	57
c. Inspect manholes and handholes.	N/A	57
d. Inspect conduit or duct system risers above ground.	N/A	57
e. Inspect lightning arresters or surge suppressors on control and telephone-type cables. Check operation and condition of the arresters and replace them as required.	N/A	Instruction book
44. WITHDRAWN–CHG 1.		
45. SPECIAL CONDITIONS.		
Inspect overhead and underground cable following any storm or circumstance that may have damaged the electrical system.	N/A	56b and 57
46.-49. RESERVED.		

CHAPTER 5. MAINTENANCE PROCEDURES

50. GENERAL.

This chapter establishes the procedures for accomplishing the various essential maintenance activities that are required for electrical power, control, telephone-type, and coaxial cables, on either a periodic or incidental basis. The chapter is divided into three sections. The first section describes the procedures to be used in making the performance checks listed in chapter 4, section 1. The second section describes the procedures for doing the tasks listed in chapter 4, section 2. The third section describes the procedures for making cable splices. Refer to Order 6000.15 for additional general guidance.

51. RESERVED.

Section 1. PERFORMANCE CHECK PROCEDURES

52. POWER CABLE TESTING.

a. Discussion. Performance tests shall be run on all power cables immediately after installation and as scheduled in chapter 4 thereafter. Tests following installation are important in that they provide assurance that no damage to the cable has occured during shipment or during installation.

b. Procedure.

(1) Insulated Power Cable, 600 Volts, Insulation-Resistance Measurements.

(a) Preliminary Test Conditions. Insulation-resistance measurements must be made with both ends of the insulated conductors disconnected from source and load terminals, arresters, and surge protectors. An insulated neutral is considered as a conductor to be tested and must be disconnected at both ends for testing purposes. The cable armor, all bare neutral conductors, and counterpoise conductors must be grounded.

CAUTION: Before disconnecting a three-phase cable, mark conductors and terminations at both ends to avoid possible facility or equipment damage due to incorrect phase rotation when the cable is reenergized.

(b) Testing. Apply a 500-volt dc voltage to the conductors being tested with an insulation-resistance test instrument and read the insulation resistance directly on the instrument meter scale. Apply the test voltage for at least 1 minute after the meter reading has stabilized, to allow even distribution of the test voltage throughout the insulation. Apply the test voltage between each insulated conductor and all other conductors, and between each insulated conductor and ground. Record the measured resistance.

CAUTION: To avoid shock from electrical energy stored by the conductor insulation, short conductors together or to ground after each insulation resistance measurement is completed.

(2) Insulated Power Cable, 5kV and 15kV, Insulation-Resistance Measurements.

(a) Preliminary Test Conditions. When the cable is installed, insulation-resistance measurements must be made with the cable's insulated conductors disconnected on both ends. Insulation-resistance measurements made thereafter must be made with the cable disconnected from transformer bushings and lightning arresters. The cable may remain connected to a pothead, terminators, open cutouts, or open switches, and with stress cones intact. A separate insulated neutral conductor (or an insulated neutral conductor that has the same insulation voltage rating as the other conductors) that is

CHAPTER 3. STANDARDS AND TOLERANCES — Continued

Parameter	Reference Paragraph	Standard	Tolerance/Limit Initial	Tolerance/Limit Operating
(a) New cable		50MΩ min at 500V dc	Standard	Standard
(b) Old cable		2.5MΩ min at 500V dc	Standard	Standard
33. COAXIAL CABLE TESTS.				
a. Gas-Filled Dielectric Cable.				
(1) Inner-to-outer conductor dielectric resistance, new and old cable.	54b(4)	Near infinite resistance at 3kV for 3 minutes (with connectors attached)	Standard	Standard
(2) Nitrogen gas pressure check, new and old cable.	54b(3)	No measurable loss of pressure	Standard	Standard
b. Solid Dielectric Cable (Inner-to-outer conductor dielectric resistance, new and old cable).	54b(4)	50MΩ min at 500V dc (with connectors attached)	Standard	3MΩ min at 500V dc (with connectors attached)
34.-39. RESERVED.				

CHAPTER 4. PERIODIC MAINTENANCE

40. GENERAL.

This chapter establishes all the maintenance activities required for electrical power and control cables on a periodic basis, and the schedules for their accomplishment. The chapter is divided into two sections. Section 1 identifies the performance checks (i.e., tests, measurements, and observations) of normal operating characteristics and functions that are necessary to determine whether operation is within established tolerances or limits. Section 2 identifies other tasks that are necessary to insure a reliable operation. Refer to the latest edition of Order 6000.15, Maintenance of Airway Facilities, for additional guidance.

Section 1. PERFORMANCE CHECKS

Performance Checks	*Reference Paragraph*	
	Standards & Tolerances	*Maintenance Procedure*
41. EVERY THREE YEARS.[1]		
a. Power Cables, 600-Volt Insulation.		
(1) Measure conductor-to-conductor insulation resistance. (Multiconductor Cable only)		
(a) New cable	31a(1)(a)	52b(1)
(b) Old cable	31a(1)(b)	52b(1)
(2) Measure conductor-to-ground insulation resistance.		
(a) New cable	31a(2)(a)	52b(1)
(b) Old cable	31a(2)(b)	52b(1)
b. Power Cables, 5kV and 15kV Insulation.		
(1) Measure conductor-to-conductor insulation resistance. (Multiconductor Cable only)		
(a) New cable	31b(1)(a) or 31c(1)(a)	52b(2)

[1]Periodic testing of building interior cables is not required unless there is an indication of deterioration. Service entrance cables installed in duct or conduit shall be considered interior cables.

contained within the overall cable assembly shield or armor must be tested for insulation resistance after disconnecting from ground rods, buried counterpoise, or grounded attachments. The cable or conductor shielding, armor, all bare neutral conductors, and the counterpoise conductor must be grounded.

CAUTION: Before disconnecting a three-phase cable, mark conductors and terminations at both ends to avoid possible facility or equipment damage due to incorrect phase rotation when the cable is reenergized.

(b) **Testing.** Apply 10kV dc voltage (for 5kV cable) or 31kV dc voltage (for15kV cable) to the conductor being tested with an insulation-resistance test instrument. Where a 10,000 or 31,000 volt dc test instrument is not available, these tests may be performed at 500 volts dc using a 500 volt dc insulation-resistance test instrument. Apply the test voltage for at least 1 minute after the meter reading has stabilized, to allow even distribution of the test voltage throughout the insulation. Read the insulation leakage current directly from the instrument meter scale. Use the instrument calibration chart to determine the insulation resistance from the leakage current read previously on the meter scale. Record the insulation resistance shown by the chart. Apply the test voltage between each insulated conductor and all other conductors in multiconductor cables, and between each conductor and ground. If the conductor-to-conductor or conductor-to-ground insulation-resistance measurements of any conductor are below the minimum resistance values shown in chapter 3, part the cable at the splices and measure the insulation resistance of each cable section to isolate the current leakage path. A low minimum resistance measurement can be caused by high leakage current in a pothead, terminator, open switch, or stress cone. Therefore, it may be necessary to disconnect these accessories during the tests if low resistance readings are encountered. If the conductor-to-conductor-to-ground insulation resistance still remains low, use a method recommended in chapter 2 to locate the defective insulation. If the cable is reconnected to a pothead or terminator that requires filling with a compound, wait until the compound has cooled or has solidified before making insulation-measurements of the repaired cable.

CAUTION: To avoid shock from electrical energy stored in the conductor insulation, short conductors together or to ground after each insulation-resistance measurement is made.

(3) **Approach Lighting System Series Loop Cable, 5kV, Insulation-Resistance Measurements.**

(a) **Preliminary Test Condition.** After discharging each series lighting loop to ground with an insulated shorting stick, disconnect both ends of the series loop cable from the lighting substation terminals. If more than one loop is diconnected, mark the cable ends for correct reconnection. All series lighting current transformers should remain connected during the tests. Defective lamps will not affect the tests.

(b) **Testing.** Apply a 10kV dc voltage to the cable being tested with an insulation-resistance test instrument, connected between one end of the cable and the substation ground. Where a 10,000 volt dc test instrument is not available, the test may be performed at 500 volts dc using a 500 volt dc insulation-resistance test instrument. Apply the test voltage for at least 1 minute after the meter reading has stabilized, to allow even distribution of the test voltage throughout the insulation. Read the insulation leakage current directly from the instrument meter scale. Use the instrument calibration chart to determine the insulation resistance from the leakage current read previously on the meter scale. Record the insulation resistance shown by the chart. If the cable fails to meet the minimum insulation-resistance values of chapter 3, sectionalize the loop to determine if the cable or isolation transformers have defective insulation.

CAUTION: To avoid shock from electrical energy stored in the conductor insulation, short the ends of the loop cable to ground after any insulation-resistance measurement is completed.

(c) ALS Loop Resistance. The total resistance of the loop, composed of conductor resistance, primary winding resistance of current transformers, and resistance of the connectors should be measured with a Wheatstone bridge and recorded. Loop resistance can be calculated by the following formula.

$$R_{total} = (R_x \times L_m) + (R_t \times T_n)$$

Where:

R_{total} = Loop resistance

R_x = Loop resistance of the cable conductor per 1000 ft (328.1 meters).

L_m = Cable length in thousands of feet (328.1 meters).

R_t = Resistance of a transformer primary winding as measured with a Wheatstone bridge.

T_n = Number of series transformers in the loop.

The value of the measured resistance should not exceed the calculated resistance by more than 20 percent.

53. CONTROL AND TELEPHONE-TYPE CABLE TESTING.

a. Discussion.

(1) **FAA-Owned, New Interior and Exterior Cable.** Test all conductors, shields, and armor for continuity. Test all conductors for shorts, crosses, grounds, and conductor-to-conductor and conductor-to-ground insulation resistance.

(2) **FAA-Owned, Old Interior and Exterior Cable.** Test all spare conductors for conductor-to-conductor and conductor-to-ground insulation resistance. If no spares are available, test a minimal number of active conductors. Select those which will have least effect on facility operation.

(3) **Circuit Addition Tests.** Test all new and old cable spare conductors or spare pairs that are to be used to establish an active circuit. Test for continuity, shorts, and grounds. Test all new circuit conductors for conductor-to-conductor and conductor-to-ground insulation resistance. If it is suspected that moisture has entered the cable, measure the insulation resistance between each of the new circuit conductors and all spare conductors in the cable.

(4) **Spliced Cable Tests.** Test all spliced conductors of new and old cables for continuity, shorts, crosses, and conductor-to-conductor and conductor-to-ground insulation resistance.

(5) **Damaged Cable Tests.** All cables subject to known or suspected damage should first have all spare conductors tested for shorts, crosses, grounds, and conductor-to-conductor and conductor-to-ground insulation resistance. Check shields and armor for continuity. When a facility outage can be tolerated, all active conductors should be tested and their shields tested for continuity. If cable damage is found, repeat the test after the cable is repaired.

(6) Additional tests may be required on voice grade circuits. See the latest edition of Order 6000.22, Maintenance of Two-Point Private Lines.

b. Procedure for Continuity, Shorts, Crosses, and Grounds Testing.

(1) **Preliminary Test Conditions.** Make these tests with both ends of each conductor disconnected from terminal strip jumper wires, surge protectors, and equipment. Cable connected together at a common terminal strip may be isolated from each other and tested separately. A conductor group shield, overall cable shield, pair shield, or designated grounding conductor may have to be disconnected from a grounded armor or other paralleled conducting path, in order to check its continuity. All shields, designated grounding conductor and armor may be grounded during tests for insulation resistance.

(2) **Continuity Tests.** Make continuity tests with an ohmmeter at the near end of the cable. Temporarily short each conductor to its paired conductor, common connector, or to a shield or armor, at the far end of the cable. Record the meter readings. Remove the temporary short at the far end of the cable after each conductor or conductor pair is tested for continuity.

(3) **Shorts, Crosses and Grounds Tests.** Make these tests with an ohmmeter connected at either end of a cable. Test between all paired or unpaired conductors within a shielded or unshielded conductor group. Test between each conductor and its nearest designated grounding conductor, pair shield, group shield, cable shield, or armor.

c. Procedure for Insulation-Resistance Measurements.

(1) **Preliminary Test Conditions.** Make these tests with both ends of each conductor disconnected from terminal strip jumpers, surge protectors, and equipment. Cables connected together at a common terminal strip may be isolated from each other and tested separately. Shields, designated grounded conductors, and armor

may remain grounded or ungrounded for insulation-resistance tests.

(2) Testing. Apply a 500-volt dc test voltage to the conductors being tested with an insulation-resistance test instrument, and read the insulation resistance directly on the instrument meter scale. Apply the test voltage for at least 1 minute after the meter reading has stabilized. Apply the test voltage between paired conductors, between conductors of a conductor group, and between conductors of an ungrouped cable. Apply the test voltage between each conductor and its designated common grounded conductor, pair shield, group shield, and overall cable shield or armor.

CAUTION: To avoid shock from electrical energy stored by the conductor insulation material, short the conductors together or to ground after each insulation resistance is measured.

54. COAXIAL CABLE TESTING.

a. Discussion. Test new solid-dielectric coaxial cable for shorts, continuity, and dielectric resistance after installation. Make periodic performance tests, and test after splicing or when damage is suspected. Test new gas-filled dielectric coaxial cable for shorts, continuity, gas pressure, and dielectric resistance after installation. Test gas-filled dielectric coaxial cable periodically and when damage is suspected. Test gas-filled dielectric coaxial cable for shorts, continuity, and gas pressure if cable has been spliced or repaired.

b. Procedure.

(1) Short-Circuit Test. Test the coaxial cable for a short circuit before the continuity test and dielectric-resistance measurements are made. Test a spliced cable for a short circuit before putting it into service.

(a) Preliminary Test Conditions. Both ends of the coaxial cable must be disconnected.

1 Solid Dielectric Cable. New cable must be tested for a short before a connector is attached to both ends. The connectors are to be attached after the continuity test and dielectric-resistance measurements are completed. After the connectors are attached to the ends of the cable, repeat the short test to ensure that neither connector is shorted internally after attachment to the cable. The connectors are to remain on the ends of the cable for all performance tests thereafter.

2 Gas-Filled Dielectric Cable. Since gas-filled coaxial cable is shipped and installed under gas pressure, the connectors are not to be removed for short-circuit testing.

(b) Testing. The test shall be made by connecting the high range of an ohmmeter between the center and outer conductors of the cable, and between the outer conductor and armor of armored cables. The meter needle may deflect toward the zero end of the ohms scale, then move slowly toward the infinite ohms end of the scale. This is caused by the ohmmeter battery voltage stress field being distributed throughout the cable dielectric. Meter needle deflection may not occur when testing a gas-filled dielectric coaxial cable for a short circuit. The meter should read infinite ohms for both types of cables.

(2) Continuity Test. Test the coaxial cable for continuity of its inner and outer conductors. If the test reveals an open conductor, the short-circuit test will have to be repeated after correcting the conductor break.

(a) Preliminary Test Conditions.

1 Solid Dielectric Cable. Disconnect both ends of the cable. Unground the outer conductor if covered by a plastic outer jacket, to prevent a metallic conduit from bridging over a possible break in the outer conductor. Test new cable for continuity before the cable connectors are attached to the ends of the cable. The connectors are to be attached after the dielectric-resistance measurements and the continuity test are completed.

2 Gas-Filled Dielectric Cable. Disconnect both ends of the cable. Unground the outer conductor if covered by an outer plastic jacket. Test new cable for continuity of the inner and outer conductors. Check conductor continuity if pressurized connectors are replaced.

(b) Testing. Connect the center and outer conductor together at the far end of the cable. Connect the low range of an ohmmeter to the conductor at the near end.

(3) **Gas Pressure Check.**

(a) **General.** Test a new gas-filled dielectric coaxial cable for gas pressure leakage after installation, even though the temperature-corrected shipping pressure is satisfactory. During cable installation, adjust the gas pressure as required by the facility operating manual or instruction book. Thereafter, test the gas pressure as part of the annual performance check. If the gas pressure is low when the annual performance test is made, pressure test the cable to locate the leak and make the necessary repairs.

(b) **Preliminary Test Conditions.** Connect the pressure gage to the coaxial cable pressure fitting, as required by the facility operating manual or instruction book. A bottle of dry nitrogen gas is required to make a pressure test.

(c) **Pressure Test.** Apply dry nitrogen gas at 15 psig (1.05 kg/cm^2) to the cable for 24 hours. At the end of the 24-hour period, shut off the gas and leave the nitrogen bottle connected.

1 **Pressure Observations.** Observe and record six successive, hourly pressure gage readings. Observe and record a seventh gas pressure reading 12 to 18 hours after the sixth observation. If no measurable loss of pressure results, the cable is acceptable. Remove the nitrogen gas bottle and pressure gage.

2 **Pressure Variations.** If a measurable variation of nitrogen gas pressure is indicated by the last five of the seven observations, and a variation is possibly due to ambient temperature changes, three additional pressure observations should be made and recorded at 24-hour intervals. If the last three observations show no measurable loss in pressure, then the cable is acceptable.

3 **Temperature Correction.** Pressure gage readings will vary with changes in temperature of the nitrogen gas in the cable. Therefore, record the ambient temperature each time a pressure gage observation is made and recorded. Use gas pressure correction factors, shown by table 5-1 before making any pressure comparisons.

4 **Correction Factor Application.** A correction factor shall be added to the gage pressure when the temperature has risen and shall be subtracted when the temperature has dropped.

TABLE 5-1. TEMPERATURE CORRECTION FACTORS FOR NITROGEN GAS PRESSURES. (Based on approximately 0.0094 pounds per degree F.)

Temperature Change		Pressure Correction Factor
°F	°C	
0	0	0.00
5	2.77	0.05
10	5.55	0.09
15	8.33	0.14
20	11.11	0.19
25	13.88	0.23
30	16.66	0.28
35	19.44	0.33
40	22.22	0.37
45	25.00	0.42
50	27.77	0.47
55	30.55	0.51
60	33.33	0.56

Example: The cable was filled with nitrogen gas and sealed at 15 psig (1.05 kg/cm^2) at 75° F (23.88° C). What should the gage read at 55° F (12.77° C)? The temperature drop is 20° F (11.11° C). From table 5-1, opposite 20° F (11.11° C) temperature change, find 0.19. Subtract 0.19 from 15 psig to get the actual pressure of 14.81 psig (1.04 kg/cm^2) at 55° F (12.77° C). If the temperature had risen to 95° F (35.00° C), the temperature rise would have been 20° F (11.11° C) also, but the factor would have been added to the gage pressure to get 15.19 psig (1.07 kg/cm^2) actual gage pressure.

5 **Final Pressure Adjustment.** After the coaxial cable has been judged acceptable, adjust the final pressure to the pressure recommended by the facility operating manual. Remove the nitrogen bottle and pressure gage.

6 **Ambient Temperature Measurement.** Measure the ambient air temperature surrounding the gas-filled coaxial cable with an accurate thermometer. If the cable is underground, the cable depth temperature may be measured with a temperature meter thermocouple

(if available) temporarily buried at cable depth. Measure and record the temperature after the fill dirt surrounding the thermocouple has reached cable depth temperature. The cable depth temperature may also be measured by lowering a thermometer into a small hole dug down to cable depth, not necessarily near the buried cable. After covering the top of the hole to prevent outside air from affecting soil temperature inside the hole, allow the thermometer to remain several hours. Then quickly withdraw the thermometer and read and record the ground temperature.

(4) Dielectric Resistance Measurement. Measure the dielectric resistance of newly installed solid and gas-filled dielectric cables. Measure the dielectric resistance when a cable is spliced, when performance tests are made, and when cable damage is suspected.

(a) Preliminary Test Conditions.

1 Solid Dielectric Cable. Disconnect both ends of existing cable. For new cable, test the dielectric resistance before the cable connectors are attached; then attach the connectors and repeat the test. The connectors are to remain on the cable for the repeated continuity and short test, and for all subsequent performance tests thereafter.

2 Gas-Filled Dielectric Cable. Disconnect both ends of the cable. Measure the dielectric resistance only when the cable nitrogen gas pressure is within the limits given in the facility instruction book.

(b) Testing. Apply the dc test voltage between the inner and outer conductor of the cable with an insulation-resistance test instrument. The test voltage for the various cables is shown in chapter 3. Apply the test voltage for at least 3 minutes to allow even distribution throughout the cable dielectric.

CAUTION: To avoid shock from electrical energy stored by the cable dielectric material, short the inner and outer conductors together after each dielectric-resistance measurement is made.

55. RESERVED.

Section 2. OTHER MAINTENANCE TASK PROCEDURES

56. OVERHEAD CABLES.

a. Inspection. Inspections for damage to wood poles, anchors, guys, grounding systems, etc., normally associated with overhead powerlines, but applicable to all types of overhead cables, are covered in the latest edition of Order 6950.18, Maintenance of Electrical Distribution Systems. Inspections listed in Order 6950.18 may be combined with inspections required in this order.

b. Procedure.

(1) Inspections. Make routine inspections in early spring and late fall. Inspect for such things as cable jacket damage, soil erosion, anchor slippage, inadequate clearances from the ground, interference from trees or structures, impending earth slides, and damaged supporting structures and hardware. Record any defects found and repair as soon as possible.

(2) Repairs. Take immediate action when a damaged overhead cable or supporting structure is found hazardous to personnel or property. If necessary, install temporary warning signs and barricades. Repair jacket and cable damage in accordance with procedures in this chapter. Repair damage to supporting structures, guys, anchors, and grounding systems in accordance with Order 6950.18. Report damage to utility-owned, privately owned, or municipally owned structures that support FAA-owned overhead lines or cables to the proper authority having responsibility for making repairs.

57. UNDERGROUND CABLE.

a. Procedure. Inspect and study the entire system, noting any abnormal conditions. Examine the entire system for excavations, washouts, rodent activity, plowing, new plantings, stakes or posts that may have been installed, evidence of vehicles that may have become stuck, and any other conditions that may have changed the terrain. Examine all conduit risers, conduits, potheads, insulators, bushings, and other equipment for discoloration or evidence of arcing or burning. Check all painted surfaces for evidence of overheating. Check for loose or missing cable grounds, inadequate cable separation, and for presence of water, fuel, or fumes in manholes or handholes. If there is snow on the ground, look for melted spots. If the route of the cable is through grass, check for burned or bare spots. Check for missing or misplaced cable markers and for missing tags on manhole or handhole covers. Any defects found should be recorded and corrected as soon as possible.

CAUTION: Use care when inspecting for loose ground wires on high voltage transformer stations, switches, oil circuit breakers, etc. Fatalities have occurred when touching an ungrounded ground wire attached to an energized transformer tank, switch, arm, etc.

b. Repairs. Take immediate action to repair underground system defects that are hazardous or that may cause deterioration or failure of facility operation. Underground cable deficiencies should be located visually or by fault location methods discussed in chapter 2. Cable repairs and splices shall be made in accordance with procedures shown in this chapter.

Section 3. CABLE SPLICING PROCEDURES

58. CABLE SPLICING.

a. General.

(1) **Definition of a Splice.** A splice is the connecting of two or more conductors with a suitable connector and reinsulating it with compatible materials applied to a properly prepared surface.

(2) **Reasons for Splicing.** There are several reasons why a cable (one or more conductors) has to be spliced. Some of the reasons are:

(a) The supplied cable is not long enough.

(b) The cable has failed or has been damaged.

(c) A tap into an existing cable (tee or wye splice) is required.

(3) **Splice Quality.** Splicing a cable is the same as rebuilding a cable; therefore, the ideal cable splice should be as strong and reliable, both electrically and physically, as the existing cable. This reliability depends partly upon the choice of splicing materials and partly upon the workmanship going into the splice. A variety of available high-quality splicing materials can withstand the electrical and mechanical stresses expected in continuous service. Thus, careful workmanship becomes of prime importance in cable splicing.

b. Splicing Material Requirements.

(1) **Power, Control, and Telephone-Type Cable Splice Materials.** The minimum requirements that splice materials must provide are conductor continuity and proper insulation of the conductor. These minimum requirements are met by constructing the splice with a conductor and insulating tape materials. Additional materials may be required for electrical stress control and for shield and armor continuity and grounding. Resin or compound encapsulation of the splice may be required to provide better moisture sealing and mechanical protection for the splice.

(a) **Connectors.**

<u>1</u> **Choice.** The proper choice of a connector is an integral and essential part of making a reliable splice. The choice of a connector is governed by the metal in the connector and the form or design of the connector.

• <u>2</u> **Connector Types.** Four types of connectors are used to splice power, control and telephone-type cable conductors. These are the crimp compression, the split-sleeve solder, the split-bolt mechanical, and the self-stripping live spring types. •

• <u>a</u> **Crimp Compression Connectors.** The crimp compression connector may be used in making an inline, tee or wye splice of a power conductor. The • connector must be the proper size for the conductor to be spliced. A connector that is too large will not grip the conductor tight enough to make a good connection, and may permit the conductor to slip out of the connector under tension. Aluminum compression connectors must be used when splicing aluminum to aluminum or aluminum to copper. An antioxidant paste must be put in the end of each aluminum conductor to be spliced before the connection can be made. Some connectors are furnished with the antioxidant paste inside. Large copper conductors can be connected with Scotchlok 10,000 series copper connectors or equal, while smaller gage copper conductors can be connected using the Scotchlok 42 series butt connectors. Aluminum or copper conductors can be spliced with Scotchlok 20,000 series aluminum connectors or equal.

b **Split-Sleeve Solder Connectors.** This connector may be used to splice large cable conductors that are not to be subjected to great tensile stress. This type of connector may also be used for splicing control and telephone type cable conductors. Care must be exercised not to overheat the thermoplastic insulation.

c **Split-Bolt Connectors.** This type is generally used when making a poured resin wye splice of a single-conductor low-voltage cable. This type should not be used to splice multiconductor cables because of its bulkiness and tendency to loosen with temperature changes, nor should it be used to splice cable rated above 1000 volts.

d **Self-Stripping Live Spring Connector.** This type of connector is generally used on the control and telephone-type cable conductors, especially in the wye tap configuration. They are available for conductor sizes No. 22 AWG through No. 10 AWG and have varying Underwriters Laboratory ratings up to and including 1,000 volts. (Minnesota Mining and Manufacturing Company's 500 series Scotchlok is an example of this type of connector.)

(b) **Tapes.**

1 **Semiconducting Tape.** This tape is rubber-based, self-fusing, electrically conductive tape, available in rolls. The tape and its liner are both imprinted to distinguish it from insulating tape. It is used for splices and stress relief cone buildup on cables with 5kV or higher insulation. Scotch 13, or an equal, is an example of this tape.

2 **High-Voltage Insulating Tape.** This tape is made of a rubber-based material especially designed for high-voltage splicing. Older self-fusing types have a removable tape liner to keep the tape layers from sticking to each other, but the tape will unroll if dropped. Scotch 23 or an equal is an example of this tape. The newer nonfusing types do not have a tape liner, will not unroll when dropped, and can be applied while using gloves. Because of its low dielectric constant, it can be used to replace the dielectric material in certain types of coaxial cable splices. Scotch 130C or an equal, is an example of this tape.

3 **Vinyl Plastic Electrical Tape.** This tape is used primarily for its moisture and scuff resistance properties. It is generally used alone to splice conductors or cables with 600-volt or lower insulation, and should be able to perform in a continuous temperature environment of 105°C (221°F).

It is used to form a liquid-tight envelope to contain the resin or compound when making a pressure splice. It is available in several thicknesses and widths. Scotch 33+ and 88, or their equals, are examples of this tape.

4 **Cloth Restricting Tape.** This tape is not an insulating tape. It is used only for wrapping the outside envelope of a pressure splice to keep it from bursting when resin or compound is injected. Scotchcast P-4, or an equal, is an example of this tape.

5 **Screen Spacer Tape.** This tape is an extruded plastic material with perforations that look similar to window screen. It is used to build up a splice or to space two or more conductors apart within a splice, so that liquid resin or compound, applied under pressure, will saturate the splice and solidify to form conductor insulation. This tape is also used as filler material to round out irregular shapes within the splice and to round out the splice body, so that liquid resin or compound, injected under pressure, will saturate the splice and harden into a splice having good electrical and mechanical properties. Scotchcast P-3, or an equal, is an example of this tape.

6 **Electrical Shielding Tape.** This non-stretchable tape is knitted from small, tinned copper wire into a tubular shape that is flattened and rolled. It is used to rebuild the shielding of a splice and serves as the conducting surface of a stress-relief cone. Scotch 24, or an equal, is an example of this tape.

(c) **Splice Encapsulation Materials.** Poured and pressure splices are made using a liquid encapsulation resin or compound and other materials to form the splice body. These may be either reenterable or non-reenterable, depending on the compound used to form the splice body. A reenterable splice is encapsulated with a material that can be split and broken away should there be a requirement to regain access to a splice. A non-reenterable splice is made of a permanent compound.

1 **Poured Splice Encapsulation Materials.** A poured splice is made by first covering the splice area with parts of a preformed plastic shell kit. The liquid encapsulating material is poured into the shell and hardens. The shell becomes a part of the splice and is not removed. Preformed plastic shell kits are available in various sizes to make in-line and wye splices of single conductor cables, with a voltage rating up to 5kV. Scotchcast kits series 82-A, 82-B, 90-B or equals are examples of kits used to splice 600V to 5kV power cables. Scotchcast kits series 72-N and 78-R or equals are examples of kits used to splice multiconductor, control, and telephone-type cables up to 1000 volts. On the smaller gage control and telephone-type cables, proper kit series selection is necessary to prevent conductor insulation damage caused by resin or compound heat. The conductor connector(s) and the liquid encapsulating resin or compound are not furnished with the kit. An epoxy resin, Scotchcast 4, or equal, should be used for splicing 600V and 5kV insulating cables. A polyurethane compound, Scotchcast 4401 or equal, should be used for splicing control and telephone-type cables.

2 **Pressure Splice Encapsulation Materials.** A pressure splice is made by wrapping the spliced conductor(s) with screen spacer tape to form the splice body. An injection fitting is taped to the splice body, and the splice body is covered with vinyl tape to prevent leakage of the liquid encapsulating resin or compound. The splice body is then wrapped with a restricting tape to resist bursting when the liquid epoxy resin or polyurethane compound is injected under pressure to saturate the screen spacer tape. The pressure splice is used to make in-line, tee, or wye splices in power, control, or telephone-type cables that are too large or too irregular in shape to accommodate a poured splice. Scotchcast 4, or equal, should be used for power cable splices. Scotchcast 2104 and 2114, or equal, are used for control and telephone-type cable splices. Scotchcast 2114 is an example of reenterable splice body compound. Scotch 2104 is a non-reenterable compound.

3 **Poured, Flexible Field Constructed Mold.** A flexible film mold with a porous webbing is used to insulate and seal odd size and shape splice configurations. This type of splice is also used to make three-way or four-way type splices. After the flexible film has been wrapped around the connector (the proper spacing is given by the porous web), the liquid encapsulating material is poured into the mold. The voltage rating of these splices is 1000 volts maximum. Scotchcast 85 series Multimold splice kits or equal should be used.

(d) **Heat-Shrink Tubing.** Heat shrinkable tubing is manufactured from cross-linked polyvinyl chloride or polyolefin family materials and is available on spools or in cut lengths. The ratio of its inside diameter before heat shrinking to its inside diameter after heat shrinking is generally 2 to 1 or 3 to 1, depending upon the material and its thickness. The wall thickness is generally classified as either "thick" or "thin" by the manufacturer. Thin-wall tubing is more prone to split when shrunk over severe configuration changes and generally cannot be shrunk with the use of an open flame under field conditions. Some tubing is manufactured with an internal sealant that provides better sealing when shrunk over the splice. The tubing requires approximately 250° (121°C) for shrinkage to take place. Most tubing is shrunk with a heat gun. Some flame resisting types may be shrunk with an open flame. When using open flame, use extreme caution around personnel and various combustible materials. Tubing from Sigmaform Corporation, Special Industries, or Essex International, or their equals, should be used. Because of the high heat required, this method is generally not used on control and telephone-type cable splices. The high heat can damage the individual conductor's insulation.

(e) **Prestretched Tubing.** The prestretched tubing is an open-ended tubular ethylene propylene rubber sleeve, which is factory assembled onto a removable, collapsible core. The tubing is supplied for field application in a prestretched condition. The core is removed after the tube has been positioned for installation over an in-line connector. The full application is made without the use of heat. Minnesota Mining and Manufacturing Company 8400 series PST connector insulator is an example of this tubing.

(f) **Electrical Grounding Braid.** This braid is used for grounding shielded or armored cable splices and * terminations. It is braided in tubular form, then it is rolled flat. It has the current-carrying capacity of No. 6 AWG copper wire. Scotch 25, or an equal, should be used.

* (g) **Electrical Putty.** This material is an electrical grade rubber-based, nonvulcanizing, elastic putty * in tape form. It is used to insulate low-voltage (600 volts and below) splice connectors, and for creating a liquid resin or compound pressure dam around a grounding braid passing outside the body of a pressure splice. Scotchfil insulation putty, or an equal, should be used.

(h) **Braided, Tinned Copper Shielding.** This shielding material is similar in construction to the braided shield (outer conductor) of a solid-dielectric coaxial cable. It is manufactured in tubular form with a nominal inside diameter ranging from 1/3 inch (.838cm) to 1½ inches (3.81cm); then it is flattened and rolled. A flattened section can be rounded to tubular shape and compressed or stretched. Belden 8600 series, or an equal, braided copper shielding should be used.

(2) **Coaxial Cable Splice Materials.** The minimum requirements that splicing materials must provide are inner and outer conductor continuity and proper dielectric insulation between the two conductors. These minimum requirements can be met by making the splice with a coaxial cable connector kit or by forming the splice with various splicing materials.

(a) **Coaxial Connectors.** Various manufacturers supply connectors for splicing solid-dielectric coaxial cables of different types and diameters. The cable inner conductor is usually soldered to the center contact (male or female) of the connector. The cable outer conductor (braided shield) may be mechanically connected or soldered to the connector body. Male and female halves of the connector are required to make the splice. The connector halves are usually attached together by a threaded collar or by a bayonet-type device. Connectors for splicing gas-filled coaxial cables are usually furnished by the cable manufacturer. However, they are seldom required since gas-filled coaxial cables are not generally spliced, but are replaced if an * unrepairable fault occurs. Coaxial connectors may be waterproofed for direct earth burial by encapsulating them with compounds such as Scotchcast 2104 or 2114, or an approved equal. *

(b) **Heat-Shrink Tubing, Tapes, and Resin Splice Materials.** These materials, used to splice solid-dielectric coaxial cables, are similar to those used to splice power, control, and telephone-type cables.

(c) **Electrical Grounding Braid.** This braid is used to ground the coaxial cable armor at splices and on the cable ends. The grounding braid is the same type used for grounding power, control, and telephone-type cable splices.

(d) **Braided, Tinned Copper Shielding.** The shielding material used to build a coaxial cable splice is the same material used for control and telephone-type cable splices.

c. **Cable Splicing, General Practice.**

(1) **Splice Failures.** With the exception of accidental damage or rodent damage, most cable faults occur at cable splices. Cable splice failures are rarely caused by defective materials. In most cases failures can be attributed to:

(a) Conductors or outer jacket (sheath) not adequately prepared.

(b) Splicing materials not applied correctly.

(c) Failure to maintain proper cleanliness within the splice.

(2) **Preparation for Splicing.** Before starting the splice, place a rubber mat or piece of plywood near the work area on which to lay tools and splicing materials. The cable ends must be supported to keep them from coming in contact with the ground and should be covered to prevent entrapment of moisture when splicing in inclement weather. Leave slack cable near all splices to simplify their replacement. An exception to this requirement would be in manholes where space is limited. When trimming cables preparatory to splicing, exercise extreme care to prevent unintentional nicking or cutting of conductors, shielding, or armor. Take precautions to prevent moisture entry or other contaminants, such as dirt, oil, and foreign particles, from adhering to the exposed conductors, tapes, or other splicing materials while a splice is being made. Hands and

* tools must be kept clean and dry to avoid contamination of the splice. As each cable end is prepared for splicing, it should be overwrapped with a backward-wound (adhesive side out) layer of vinyl electrical tape such as Scotch 33+ or an equal.

(3) **Splicing Material Preparation.** Splicing materials must be protected from moisture and extreme temperatures. A satisfactory splice cannot be made if tapes are too rigid or if liquid resins or compounds are too cold to mix. All splicing material should be stored in a warm location until ready for use. In cable manufacturing, waxes, oils, and plasticizers are * liberally used and may be present on the jacket. If not completely removed, they will prevent adhesion of the tape, resin, or compound. The foreign material can be removed by applying a solvent, followed by the use of an aluminum oxide cloth. The recommended solvent is trichlorethane degreaser, NSN 6810-00-664-0387. A cable-preparation kit can be used to supply the necessary cleaning materials. This type of kit consists of a strip of nonconductive abrasive cloth wrapped under the label on the exterior of the can and a sealed easy-open can containing three lint-free, solvent-saturated nonwoven pads. Scotch A-2 cable-preparation kit is an example of this type of kit.

d. **Power Cable Splicing.** This section gives approved methods for rebuilding the various parts of power cables when making a splice. These methods are * those suggested by manufacturers of splicing materials and have been proven by field experience. Methods and materials for splicing 15kV cables are similar, with dimensions shown by manufacturers splicing diagrams. * When possible, use complete splicing kits with step-by-step cable preparation and splice insulation procedures. The conductor connector should be of the same manufacturer as the splicing kits to insure compatibility of materials and splicing instruction. Scotch splicing kits and Scotchlok connectors are examples. *

(1) **Power Cable Splice Preparation.**

(a) **Cutting Cable Ends.** The ends of the cable, whether single or multiconductor, shielded, or armored must be cut off square. If the cable has been physically destroyed by fault current or by a destructive method used to locate the cable fault, remove at least 3 feet (.91 meter) on each side of a 5kV cable fault and 1 foot (.30 meter) on 600-volt cable. Failure to do so may allow defective cable insulation to be enclosed within the splice. If not enough cable slack is available to make the splice after destroyed cable ends are removed, splice in a minimum of 3 feet (0.91 meter) of new cable, plus the required length of new * cable required to make two splices.

(b) **Outer Jacket Cleaning.** Clean the outer jacket before making a taped dry splice or making a pressure or poured splice. Often it is more convenient to clean the outer jacket before removing part of it in preparation for making the splice. Because some jacket materials are quite conductive, the jacket should never be considered as an insulator. Do not consider cable jackets as being clean although they may appear so. A knife held approximately perpendicular to the cable and pulled as a scraper, is one of the best cleaning * methods. This method removes wax, dirt, or conduc- * tive residues. Nonconductive aluminum oxide cloth * may be used for further cleaning and for roughing up the jacket surface. Failure to clean the jacket results in a weak tape, resin, or compound bond and produces a possible moisture path. Clean the jacket in all areas where tape or encapsulating material must make a * bond. The cleaned area may be temporarily covered with reverse layer (adhesive side out) of vinyl tape, such as Scotch 33+, for protection during the splicing operation. The 4-inch (10.16cm) area to be cleaned beyond the jacket to be removed, as shown by figure 5-1, is typical for power cable.

(c) **Outer Jacket Removal.** Remove the outer jacket to expose the armor, shield, or conductor insulation. The length of the jacket to be removed is shown by dimension A of figure 5-2 and will vary according to the splice instructions. Remove additional jacket equal to one-half the length of the conductor splice connector to be used. Use a sharp knife or cable stripping tool to score the jacket to a depth of approximately one-half its thickness. If the jacket is not removable with fingers or pliers, cut the jacket deeper, taking care not to nick the armor, shield, or insulation. * If the jacket is fused to the conductor insulation, on a nonshielded cable, do not attempt its removal; treat it * as part of the insulation when building the splice.

(d) **Armor Removal.** Most splices of armored cable require that the armor be removed from the cable ends. A convenient way to hold the armor during cutoff and splice buildup is with a flat, adjustable radiator hose clamp. Place a hose clamp over the armor, adjacent to the edge of the outer jacket. Locate

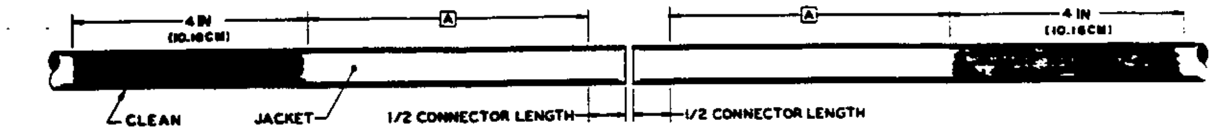


Figure 5-1. Clean Cable Jacket.

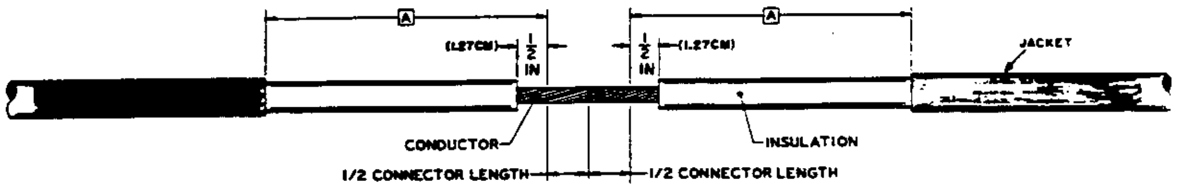


Figure 5-2. Remove Jacket and Insulation.

the hose clamp so that the distance from the outer jacket to the edge of the clamp nearest the splice is 1 to 1½ inches (2.54 to 3.81cm), depending on the splice requirements. If the armour is to be removed, score the armor with a hacksaw blade at the edge of the clamp nearest the splice. Unwrap the armor and break off at the scored mark. If the armor is to be reused to complete the splice, unwrap the armor back to the edge of the clamp, bend it back over the clamp, and tape it to the body of the cable. Leave the hose clamp on the cut or uncut armor until it must be removed for subsequent splicing operations.

(e) **Metallic Shield Removal.** After removal of the cable outer jacket, remove and cut off any bedding material flush with the edge of the jacket. There are two common types of cable shields: tape or ribbon type and drainwire type. For ribbon shielded cable remove shield, leaving 1-inch (2.54cm) exposed beyond cable jacket, and tack metallic shielding in place with solder. For drain-wire shielded cable, wrap two unstretched layers of an electrical shield tape, such as Scotch 24, over shield wires for 1-inch (2.54cm) beyond cable jacket. Tack layers in place with solder, and cut shielding wire off flush with leading edge of metallic shield tape. Use caution while cutting through the shield to not nick the semiconductive bedding tape (5kV shielded cable) or an inner jacket or the conductor insulation. Remove the shield bedding material and cut off with scissors, leaving a portion protruding from under the cut edge of the shield, as required by the splice dimensions.

(f) **Inner Jacket Removal.** Some cables may have an inner jacket between the cable insulation and their surrounding shield or armor. Cut the inner jacket to protude from beneath the shield or armor as required by the dimensions of the splice. This inner jacket material is conductive and should be handled accordingly.

(g) **Cable Semiconducting-Material Removal.** The most common cause of splice failure is improper removal of cable semiconducting material. All of this material must be removed in order for the splice to work. Remove semiconducting material, leaving ¼ inch (.64cm) exposed beyond cable metallic shielding. Do not cut into cable insulation. Be sure to remove all traces of this material from exposed cable insulation by cleaning with solvent and nonconductive abrasive cloth (available in a Scotch cable-preparation A2 kit or equal).

(h) **Insulation Removal.** Remove the insulation from the end of each conductor to be spliced. Remove conductor insulation equal in dimension to one-half the length of the conductor splice connector to be used. Additional insulation should be removed from the conductor to allow for application of tape between the ends of the connector and the end of the insulation. The one-half inch (1.27cm) additional insulation removed is minimum for large cable. Additional insulation removal for smaller cable may be less. The insulation material may be cut with a knife. Use care so as to not nick the conductor.

NOTE: Load cycling of a conductor causes heating and cooling of the conductor.

Nicked conductor strands may crystallize and break. Current-carrying capacity is reduced and splice failure may result if the broken strand springs away from the other strands to penetrate insulation. Also a corona arc may result in high voltage cable.

(h) **Strand Shielding Removal.** Remove the semiconducting strand shielding material from the conductor and cut off at the end of the insulation, using caution not to nick the conductor. Pieces of strand shielding left protruding from under the insulation will cause unwanted stress concentration in a 5kV or 15kV cable splice or termination.

(2) **Power Cable Splice Buildup.**

(a) **Conductor Insulation Penciling.** If recommended by the splice manufacturer, pencil 5kV conductor insulation before splicing, as shown by figure 5-3. Penciling should be done with a sharp knife, making a conical tapering of the insulation from its outer diameter down to its junction with the conductor. Dimension B of the figure is determined by the splicing instructions; or if instructions are lacking, taper at approximately 45 degrees to 60 degrees with reference to the axis of the conductor. The penciled area must be free of nicks or gouges so that air pockets will not be trapped during subsequent taping for the splice buildup. Smooth the penciled tapes with the abrasive cloth from the A-2 Scotch cable-preparation kit, or an equal.

(b) **Conductor and Insulation Cleaning.** Scrape all semiconducting bedding tape (shielded single conductor cable) or semiconducting shielding tape (multiconductor cable) from the conductor insulation with a knife blade. Scrape the exposed conductor free of any bits of insulation or strand shielding. Scrape the oxide from an aluminum conductor. Clean and smooth the insulation with abrasive cloth and clean with a lint-free cloth moistened with trichloroethane, as provided in the Scotch A-2 kit or equal. Do not saturate the conductor strands, bedding tape, or semiconducting shielding tape. Scrape and clean all conductors and their insulation. Do not touch the conductor. The insulation may be temporarily covered with a reverse layer (adhesive side out) of vinyl tape such as Scotch 33+. The tape should not leave a residue when removed from the insulation. The insulation and conductor(s) of 600-volt cable should be scraped in a similar manner for splice preparation.

(c) **Conductor Connector Installation.** The recommendation of the splice manufacturer for the conductor should be followed to insure compatibilities of materials and dimensional sizing. If solder connectors are used, insure that the heat of soldering will not damage unprotected insulation. Self-stripping live spring connectors may be used on power cable up to No. 10 AWG and 600 volts. Follow the connector manufacturers installation instructions. Aluminum compression connectors must be used to splice aluminum conductors because of the difficulty in soldering them together using a split-solder connector. Split-bolt connectors should not be used to splice 5kV cable conductors. Connectors used to splice 5kV conductors must be scraped or filed after attaching them to the conductors, to remove burrs or solder tips that can cause uneven electrical stress within the splice. Figure 5-4 shows the ends of two conductors fastened together with a connector before tape application.

(d) **Tape Application Method.** Apply all tapes used to build the splice in level-wound layers, as shown by figure 5-5. The layers should be half-lapped unless shown otherwise by the splice instructions. The arrows shown on the figure indicate that tape layers are wound in both directions. Successive layers are made progressively narrower. The last layer of tape should be at the maximum diameter of the tape buildup over the conductor connector(s). Level winding produces good form and tapered ends without uphill or downhill wrapping. If the diameter is first allowed to build up at the center of the splice, all subsequent wrapping is either uphill or down-hill, making good workmanship difficult.

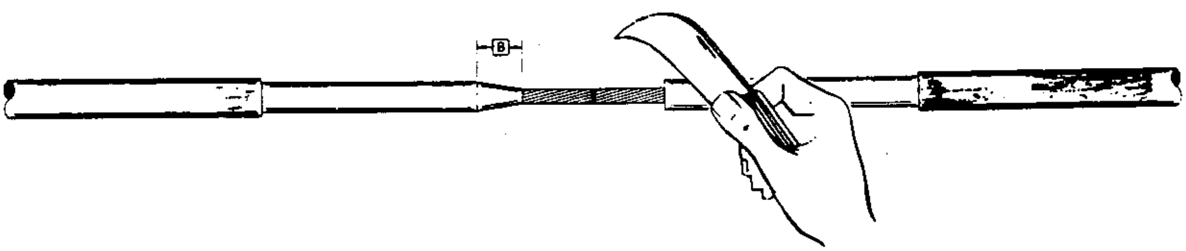


Figure 5-3. Pencil Insulation.

Figure 5-4. Install Connector.

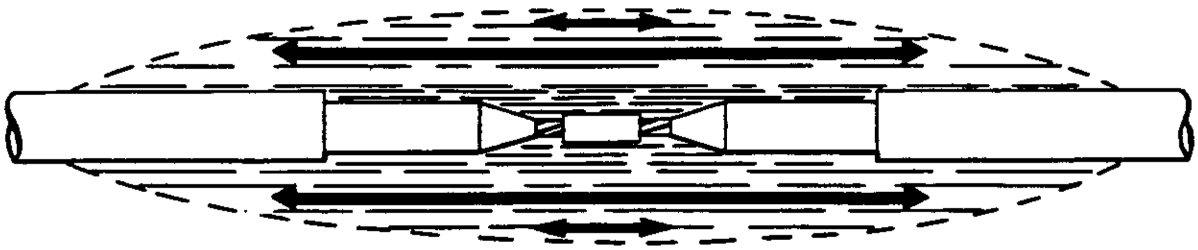


Figure 5-5. Splice Tape Buildup.

(e) **Semiconducting Tape Application.** Cover 5kV conductor connectors with at least one half-lapped layer of semiconducting tape, as shown by figure 5-6. Before covering the connector of a 5kV conductor with any kind of tape, small pieces of semiconducting tape material should be used to fill in the dimples or indents made on a connector by the crimping tool. The ends of the connector shall be filled and rounded with semiconducting tape to prevent formation of air pockets, which can cause ozone generation within the splice. When the 5kV cable splice instructions require the covering of the connector with semiconducting tape, the tape should be stretched almost to its breaking point to make the half-lapped layers between the ends of the connector and the end of the tapered area of the insulation, as shown by figure 5-6. Tape the end of the penciled insulation at least 1/16 inch (1.58mm) to cover the ends of the strand shielding between the insulation and the conductor. Be certain to remove the nonconducting backing material from the semiconducting tape before applying. Relax tension from the layer of semiconducting tape when covering the connector. Limit touching of the semiconducting tape and insulation during and after wrapping to only that required to make the splice.

NOTE: Certain splices require that screen-spacer-tape splice body buildup be applied over the bare or tape-covered connector to a thickness equal to 1¼ to 2 times the thickness of the conductor insulation. Caliper the insulation thickness and diameter of the connector after it has been covered with semiconducting tape, and record the measurement to calculate the diameter of the splice body buildup over the connector.

(f) **High-Voltage Tape Application.**

1 When constructing a dry splice, stretch high-voltage insulating tape to approximately three-fourths of its original width and apply the tape in half-lapped

Figure 5-6. Apply Semiconducting Tape, 5KV Connector Conductor.

layers over the bare conductor between the ends of the connector and the end of the penciled insulation. Tape tension should be slacked off when covering the connector with at least one half-lapped layer and then continued, building half-lapped layers to the thickness of the conductor insulation. Additional half-lapped layers of high-voltage tape should be used to build a dry splice to where the tape thickness over the center of the connector is 1½ to 2 times the thickness of the conductor insulation.

* 2 **Semiconducting Tape.** Wrap one half-lapped layer of a semiconducting rubber tape, such as Scotch 13 or equal, over the splicing tape, extending over cable semiconducting material and onto cable metallic shield ¼ inch (.64cm) at each end. Wrap one half-lapped layer of a metallic electrical shielding tape, such as Scotch 24 or equal, over semiconducting rubber tape, overlapping ¼ inch (.64cm) onto cable metallic shielding at each end. Solder ends to metallic shielding. Wrap one half-lapped layer of a vinyl plastic electrical tape, such as Scotch 33+ or equal, covering entire area of shielding braid. Attach a ground braid, such as Scotch 25 or equal, by soldering it to cable metallic shielding at each end.

3 **Splice Jacket (Tape Method).** Wrap four half-lapped layers of high-voltage rubber tape, such as Scotch 23 or Scotch 130C or equal, over entire splice 2 inches (3.08 cm) onto cable jacket. Tightly stretch the rubber tape to form moisture seal. Wrap two half-lapped layers of vinyl plastic electrical tape, such as 33+ or equal, over entire splice 1 inch (2.54 cm) beyond rubber splicing tape.

4 **Splice Jacket (Resin Method).** Overwrap conductor or conductors with four half-lapped layers of spacer tape, such as Scotchcast P-3 or equal, and overlap cable jacket at least 3 inches (7.62 cm) or a specified distance and thickness shown by the splice instruction. *

(g) **Screen Spacer Tape Application.** Use spacer tape to make in-line, tee, or wye, epoxy resin or polyurethane compound pressure splices in single or multiconductor cables insulated to 600V, or in single conductor cables insulated to 8kV. Spacer tape should be wrapped over each conductor and connector as shown by figure 5-7. Rolled spacer tape may be used to wedge conductors apart for better encapsulation, as shown in figure 5-7. Use spacer tape to build the splice over shield or armor that is to be encapsulated within a similar splice. The ends of the armor should be wrapped over the splice and bolted together before application of the screen spacer tape. Wrap the spacer tape over the cleaned and scraped outer jacket for a minimum distance of 3 inches (7.62cm), or a specified distance shown by the splice instructions. The splice body outline is shown by the dashed line in the figure.

(h) **Moisture-Proof Tape application.** Apply vinyl tape on the outside of a dry splice for waterproofing and to provide resistance to abrasion. Apply vinyl tape over the spacer tape body of a pressure splice to

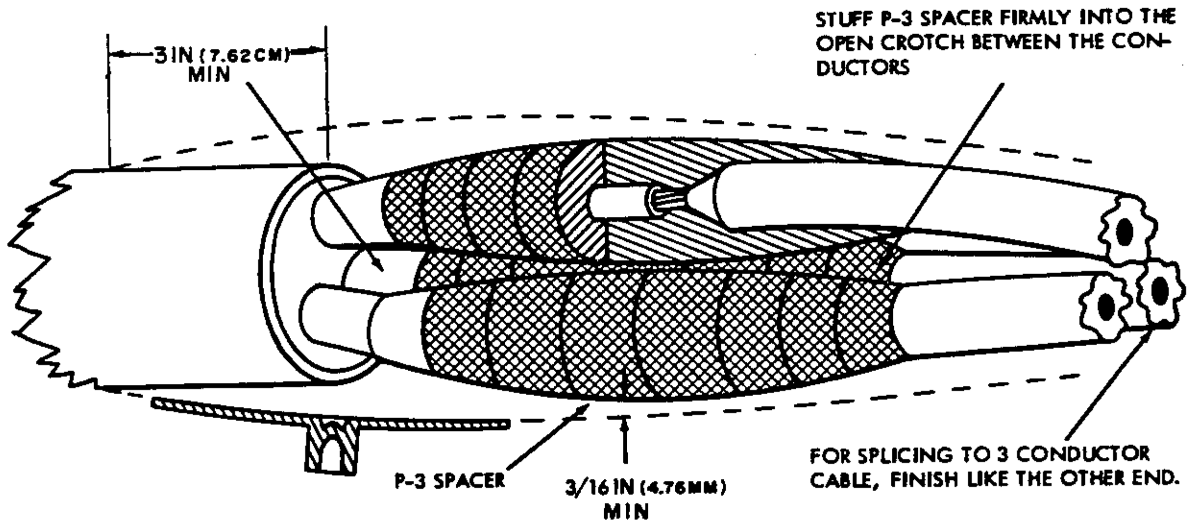


Figure 5-7. Pressure Splice, Multiconductor, 600V, Unarmored Power Cable.

* contain the liquid resin or compound. This tape, such as Scotch 33+ or equal, shall be capable of performing in a continuous temperature environment of 105°C. * Cover the spacer tape body, except for approximately 1/16 inch (1.58mm), to provide a resin or compound vent for each conductor or cable entering the splice. Use vinyl tape to anchor the injection nozzle to the spacer tape pressure splice body. Apply all vinyl tape in half-lapped layers.

* (i) **Restricting Tape Application.** Apply restricting tape, Scotchcast P-4 or equal, in half-lapped layers over the vinyl tape envelope of a pressure splice body. The restricting tape prevents bursting of the splice as the epoxy resin or polyurethane compound is * injected into the splice under pressure. Apply the restricting tape so as not to obstruct the resin vents of the splice.

(j) **Shielding Tape Application.** Rebuild the cable shield over the spacer tape body of a pressure splice with shielding tape. Solder the shielding tape to the cable shield on one side of the splice, half-lap wind the tape loosely over the splice body, then solder to the shield on the other side of the splice. Shielding tape may also be applied to provide armor continuity within a pressure splice. Solder the shielding tape to the armor on both sides of the splice.

(k) **Electrical Grounding Braid Application.** Use grounding braid to ground the shield of an unarmored cable at the splice or to ground the end of the shield at a terminator or stress relief cone. Use the braid to ground the armor of a shielded or unshielded cable at each splice and at the ends of the cable. Use the grounding braid inside a dry splice or pressure splice to provide armor electrical continuity. The grounding braid is to be brought outside the splice before completing the splice body. Make a solder block in the electrical braid to prevent moisture entry into the splice through the braid. The solder block is made by saturating a portion of the braid with 60-40 solder. Extend the solder block from outside the splice to well within the splice body.

(l) **Electrical Putty Application.** Electrical putty tape may be used instead of vinyl plastic tape to make a pressure dam surrounding the solder-blocked electrical grounding braid. The electrical putty tape is used to aid in the prevention of moisture entry in the splice and to anchor the braid inside a pressure splice. The electrical putty and vinyl tape may be used as a braid anchor applied outside the encapsulated splice body. Placing the tape braid anchor outside the pressure splice will aid in minimizing the breaking away of the thin edge of the pressure splice body from the cable jacket when stress is placed on the grounding braid. Make the pressure dam by wrapping one layer of electrical putty tape around the cable outer jacket. Press the solder-blocked portion of the grounding braid into the first layer of electrical putty tape. Use small pieces of electrical putty tape to provide two thicknesses over the top and sides of the solder block. Wrap a layer of electrical putty tape around the able to cover the first layer and two thicknesses of electrical putty tape. Press the putty tape firmly to make good contact with all sides of the solder-blocked portion of the grounding braid, then overwrap it with two layers of vinyl tape.

(3) **Pressure Splice Buildup, 8kV Cables Maximum.**

(a) **Insulation Preparation and Penciling.** Clean the insulation on both sides of the splice connector. The insulation of a 5kV rubber insulated conductor should be penciled as shown by figure 5-8. The thin insulation used on some 600V conductors and the conductors of control and telephone type cables, does not have to be penciled.

(b) **Connector Attachment and Taping.** After attaching the connector to both conductor ends, cover it with semiconducting tape (5kV cable). Wrap the conductors of multiconductor power cable separately with screen spacer tape as shown by figure 5-7.

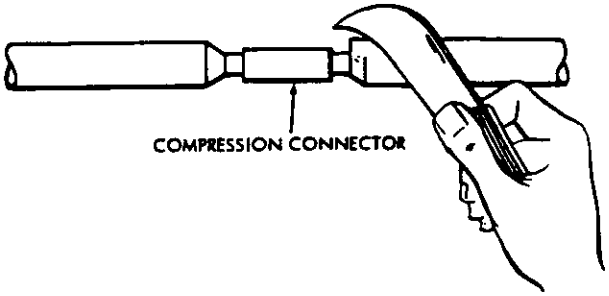


Figure 5-8. Pressure Splice, Preparing Cable End and Installing Connector.

A single conductor cable does not have to be separately wrapped with screen spacer tape before building the splice body with screen spacer tape.

(c) **Splice Body Buildup for a Pressure Splice.** Apply the spacer tape in half-lapped layers over the single or bundled conductors, and out over the ends of the cleaned outer jacket (figure 5-9) for about 3 inches (7.62cm) or as directed by the splicing instructions. After building the layers of spacer tape to about 3/16 inch (4.76mm) thickness over the conductor(s), cut off the spacer tape and anchor its end with a piece of plastic tape. Apply in a similar manner to build the splice body of a tee or wye splice.

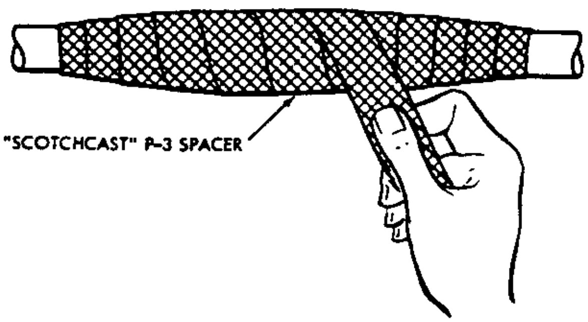


Figure 5-9. Pressure Splice, Applying Screen Spacer Tape.

(d) **Injection Fitting and Vinyl Plastic Tape for a Pressure Splice.** Locate the resin injection fitting, with its open end facing up, near one end of the spacer tape splice body, as shown by figure 5-10. Attach to injection fitting to the splice body with vinyl plastic tape as shown by figure 5-11. Cover the spacer tape splice body with two half-lapped layers of vinyl plastic tape as shown by figure 5-12, but leave 1/16 inch (1.58mm) of spacer tape exposed on each end of the splice for a resin vent. Figure 5-13, on page 57, shows the location of the injection fitting and the method of wrapping the plastic tape for a pressure tee splice.

(e) Restricting Tape for a Pressure Splice. Apply two one-half lapped layers of restricting tape over the vinyl plastic tape, as shown by figure 5-14, using care to not cover the resin vents. Apply in a similar manner for a tee or wye splice.

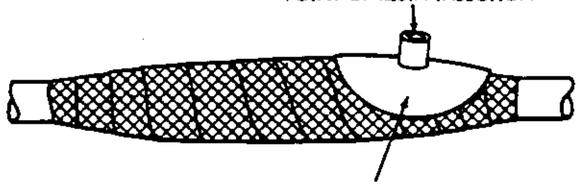


Figure 5-10. Pressure Splice, Locating Injection Fitting.

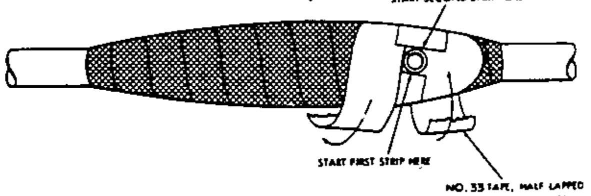


Figure 5-11. Pressure Splice, Attaching Injection Fitting.

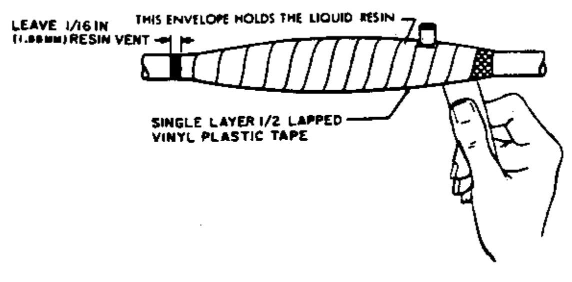


Figure 5-12. Pressure Splice, Applying Plastic Tape Envelope.

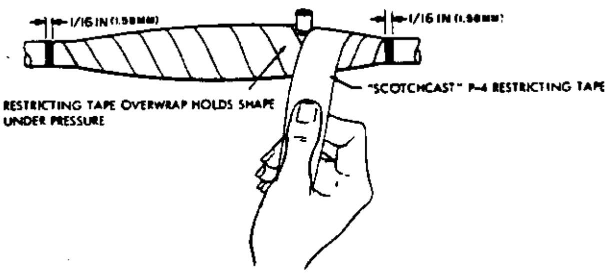


Figure 5-14. Pressure Splice, Applying Restricting Tape.

(f) Pressure Gun Preparation. The pressure gun should be prepared by first mixing the two-part resin compound, attaching the injector nozzle to the resin mixing bag, and inserting it in the pressure gun.

(g) Resin Injection, In-line Splice. Before injecting the resin, wrap two layers of plastic tape over the resin vent nearest the injection fitting, as shown by figure 5-15. Inject resin into the splice slowly to drive air out the open vent farthest from the injection fitting. When resin appears at the open vent, stop the injection and wrap two layers of vinyl tape around the open vent to seal it. Remove the tape to open the vent nearest the injection fitting. Inject resin into the splice until it appears at the open vent. Stop the injection, remove the pressure gun, and wrap the vent with two layers of vinyl tape. Remove the resin bag from the pressure gun and clean the gun. Do not move the cable until the resin has hardened.

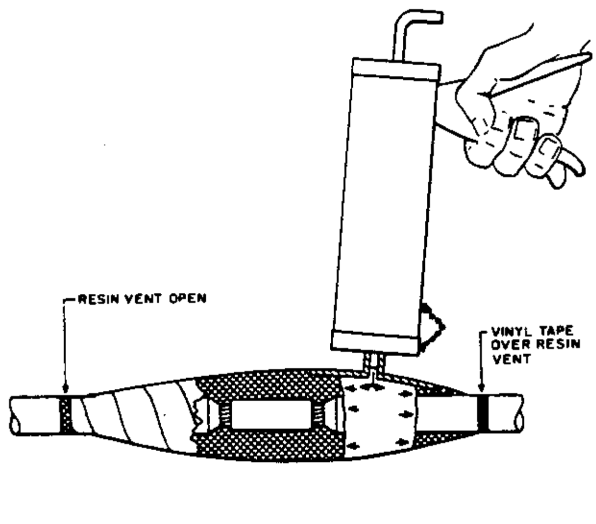


Figure 5-15. Pressure Splice, Saturating Splice.

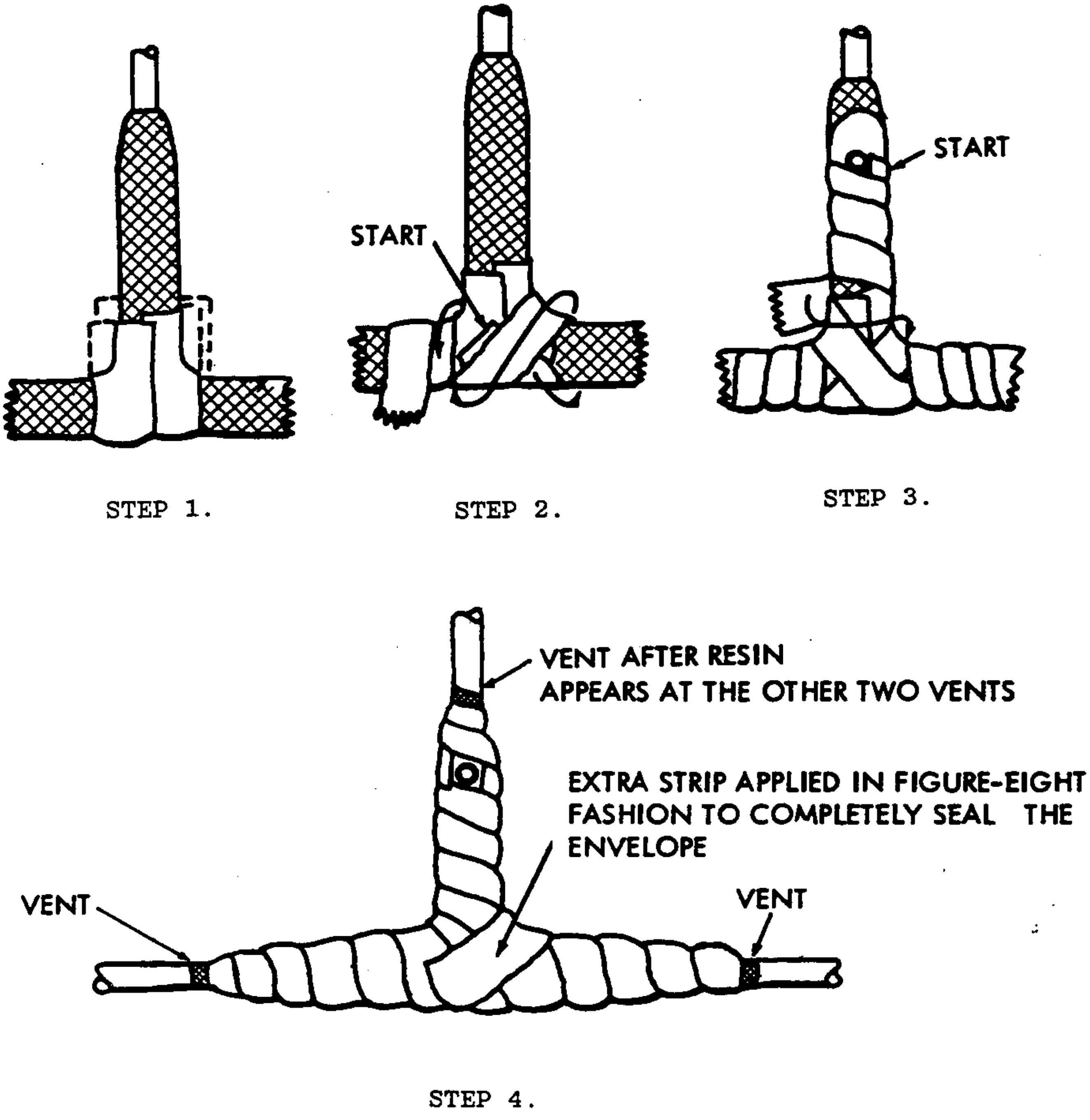


Figure 5-13. Pressure Tee Splice. Applying Plastic, Tape Envelope.

(h) **Resin Injection, Tee and Wye Splices.** Prior to injecting resin into a tee or wye splice, wrap two layers of vinyl tape to close two vents nearest the injection fitting. After resin appears at the vent farthest from the injection fitting, close it with two layers of vinyl tape. With the vent nearest and farthest away from the injection fitting sealed with vinyl tape, open the remaining vent. Inject resin until it appears at the open vent. Close the vent with vinyl tape and open the vent nearest the injection fitting. Inject resin into the splice until it appears at the open vent. Remove the pressure gun and seal the vent with vinyl tape. Remove the resin bag from the pressure gun and clean the gun as required. Do not move the cable until the resin has hardened.

(i) **Tape Removal.** After the resin has hardened, the restricting tape, vinyl tape, and injection fitting may, be removed from the splice. Removal is not necessary for proper operation.

(j) **Cable Use.** The cable may be energized after the resin has hardened.

(4) **Poured Resin Splice Kit Application** (Figure 5-16).

(a) **In-line Splice Poured Resin Kit.** Figure 5-16 shows the preparation and procedure for making an in-line poured slice for a single conductor, 600V or
* 5kV, unshielded cable. Different kits are suitable for tapping and splicing multiconductor, 600V and 5kV insulated, shielded or unshielded, unarmored cable. On small gage multiconductor control and signal or telephone-type cables, the heat of the epoxy resin No. 4 in the 82-A series kits may damage the conductor's insulation. The polyurethane of Scotchcast 72-N and 78-R series or their equal should be used on these types of cables. The poured resin kits are not suitable for splicing a multiconductor, 5kV insulated cable; but is suitable for splicing a multiconductor, 600V insulated, unshielded, unarmored cable. Four in-line splice kits may * be used with cables of No. 10 AWG to 400 MCM conductor size, and a variety of connectors may be used. The maximum diameter of a connector is shown for each kit. The connectors of multiconductor cable may be staggered, and conductors held apart by spacer tape wedges or by wrapping individually with spacer tape, similar to figure 5-7.

(b) **Wye-Splice Poured Resin Kit.** Figure 5-16 shows that two splice kits for wye splices are availa-
* ble. A split-bolt, self-stripping live spring, or crimped compression connector may be used to connect the tap conductor to the main conductor. A large main conductor can be tapped if a crimp connector is used with either kit. One kit size can be used to wye-splice an unshielded, single-conductor cable with up to 5kV insulation or to wye-splice a multiconductor cable with up to 600V insulation. The other wye splice kit is usable for small single or multiconductor cables insulated for 600 V or less. The splicing technique for these kits is similar to the in-line poured splice.

(5) **Approach Lighting System (ALS) Cable-Connector Splice Kit Application.** Figure 5-17 shows a typical quick-disconnect cable splice kit, suitable for splicing nonarmored, nonshielded 5kV series lighting cable, such as used for the ALS. Other kits are available for two-conductor, 5kV nonarmored, nonshielded direct-earth-burial (DEB) cable. All kits are furnished with a section of conductor attached to the male and female halves of the connector. The connector is spliced into the 5kV ALS cable, using a dry or poured resin splice for single-conductor cable or a pressure resin splice for two-conductor cable. Silicone grease is inserted into the connector halves before joining them together. After excess grease is removed from outside the connector, it should be wrapped with four half-lapped layers of vinyl tape if buried in a trench.

(6) **Power Cable Splices, Typical.**

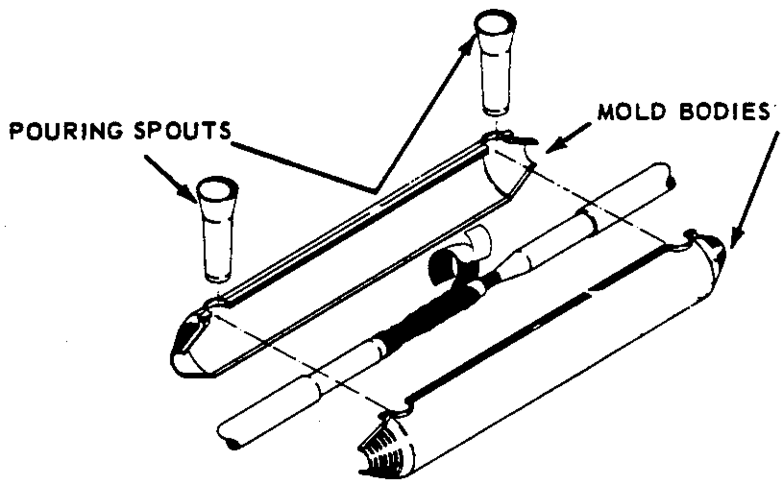
(a) **In-line Dry Splice, 600V and 5kV, Single-Conductor, DEB Cable.** Figure 5-18, on page 64, shows dimensions and materials recommended for this splice. Splice dimensions may be reduced when splicing conductors smaller than the No. 6 AWG shown by the figure. This splice should be covered with an electrical coating to give better protection against moisture
* entry and corrosive conditions when buried. Scotchkote electrical coating or equal is an example of this coating. A dry splice for 15kV cable is made in a similar manner, in accordance with manufacturers instructions. *

* (b) **In-line Pressure Splice, 5kV, Single-Conductor, Shielded Cable.** Figure 5-19 shows this splice. See the materials manufacturers instructions for further details. The solder block of the external ground braid must extend inside the splice encapsulation.

(c) **In-line Pressure Splice, 600V and 5kV, Single-Conductor, Unshielded Cable.** Figure 5-20 shows this splice. See the materials manufacturers instructions for further details. When splicing 600V conductors, it is not necessary to cover the connector with
* semiconducting tape as shown.

(d) **Pressure Resin Tee-Splice, 600V and 5kV, Single-Conductor, Unshielded Cable.** Figure 5-21 shows the construction of this splice. See the splice kit

INSTRUCTIONS



Scotchcast® BRAND
SPLICING KIT 82-A1

DESIGNED FOR USE IN WEATHER EXPOSED OR DIRECT BURIAL LOCATIONS

For making inline (straight) splices on unshielded synthetic insulated cables rated 5 KV and lower. For multi-conductor cables rated up to a maximum of 600 volts.

CONDUCTOR SIZE*
MAXIMUM #2 AWG

* Cable O.D. cannot exceed 5/8 inch.

CONNECTOR O.D. (COMPRESSION SLEEVE)
MAXIMUM 13/32 INCH

CONTENTS OF "SCOTCHCAST" KIT NO. 82-A1

- 2 Plastic Mold Halves
- 2 Strips "SCOTCH" Brand Electrical Tape No. 23
- 2 Pouring Spouts
- 1 "SCOTCHCAST" Resin No. 4 in "UNIPAK" Brand Container – Size A

Figure 5-16. Poured Splice Kit Instructions.

IMPORTANT INSTRUCTIONS – READ CAREFULLY

1. PREPARE CABLE

Thoroughly scrape all wax and dirt five inches back from each cable end. Prepare cable ends exactly as shown in Fig. 1 and chart below. Do not cut insulation when removing outer sheath.

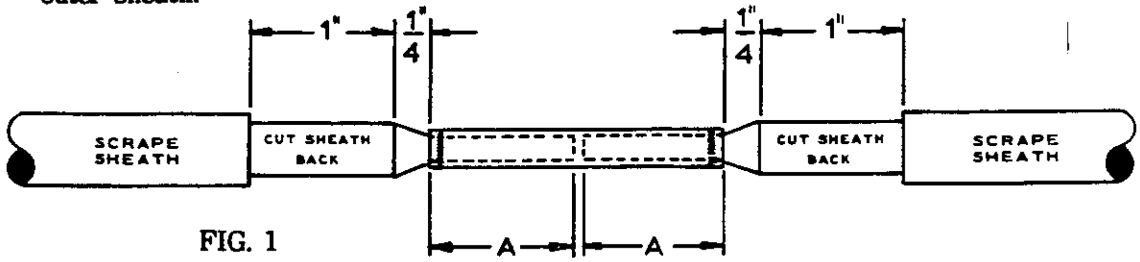


FIG. 1

For cables without removable outer sheath, a smooth 1¼" pencilled section should be substituted for the 1¼" stepped section in sketch above.

AWG	A	A	CONNECTOR
10, 8, 6, 2	As required to fit connector		Compression type connector
Multi-conductor Cable* (Max. 600 Volts)	Sheath opening not to exceed 4½ inches		

*Stagger individual connections and insulate with "SCOTCH" Brand Electrical Tape No. 23.

2. MAKE CONNECTION

Join conductors with compression type connectors.
Follow connector manufacturer's instructions.

3. TAPE OVER CONNECTOR AREA using one strip of "SCOTCH" Brand Electrical Tape No. 23. Apply one layer half lapped over connector area only. DO NOT wrap No. 23 tape beyond pencilled area. SEE FIG. 2.

IMPORTANT: Stretch tape to 1/2 original width.

4. INSTALL MOLD BODY

Trim mold ends with knife to fit cable slightly loose. Hold mold halves in place centered over splice. Snap mold halves together firmly, then put pouring spouts in holes. Check to see that both seams are carefully snapped together. SEE FIG. 2.

Figure 5-16. Poured Splice Kit Instructions — continued.

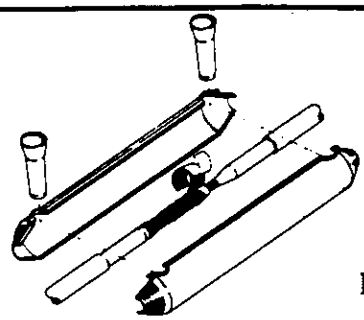


FIG. 2

IMPORTANT: Cables and connector must be centered in mold.

5. TAPE ENDS OF MOLD BODY around cable to seal. Use "SCOTCH" Brand Electrical Tape No. 23, supplied with this kit. SEE FIG. 3.

   IMPORTANT: Stretch tape to 1/2 original width.

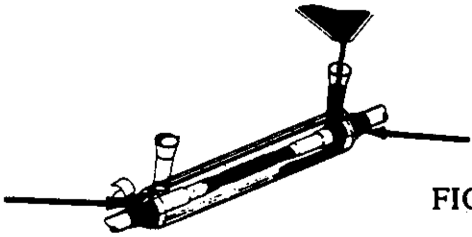


FIG. 3

6. POUR SPLICE

   Position splice level. Mix resin thoroughly per instructions on "UNIPAK" Guardbag. Pour resin immediately after mixing. Fill mold through one spout until both spouts are completely filled, (see Fig. 3.)

   When resin has solidified and cooled, splice may be put into service. Slip off spouts if desired.

GETTING THE MOST OUT OF "UNIPAK"

This is the best way to remove last bit of resin from "UNIPAK". Pour most of resin into mold, then draw bag over edge of a tool box, board, etc., as shown in picture.

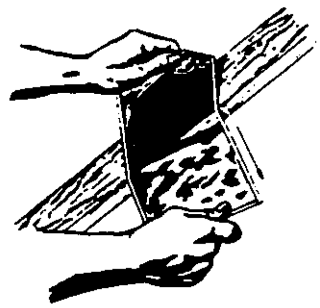


Figure 5-16. Poured Splice Kit Instructions — continued.

OTHER "SCOTCHCAST" BRAND SPLICING AND TERMINATING KITS FROM 3M COMPANY

Scotchcast BRAND SPLICING KITS

KIT NUMBER	CONDUCTOR SIZE	CONNECTOR O.D.
82-A (Inline)	Min. #10 AWG Max. #2 AWG	Max. 13/32"
82-A1 (Inline)	Max. #2 AWG	Max. 13/32"
82-A2 (Inline)	Min. #2 AWG Max. #3/0 AWG	Max. 5/8"
82-A3 (Inline)	Min. #3/0 AWG Max. 400 MCM	Max. 1"
82-B1 (Tap)	Cable O.D. Min. 1/4" to Max. 5/8"	Split Bolt Max. #4 AWG Crimped Max. #2 AWG
90-B1 (Tap) 600 V. Max.	Feeder Cable O.D. 1/2" to 13/16" Branch Cable O. D. Max. 3/8"	Split Bolt Max. #1/0 AWG Crimped Max. #2/0 AWG

NOTE: 82-A Series rated upto a max. of 5 KV.

Figure 5-16. Poured Splice Kit Instructions — continued.

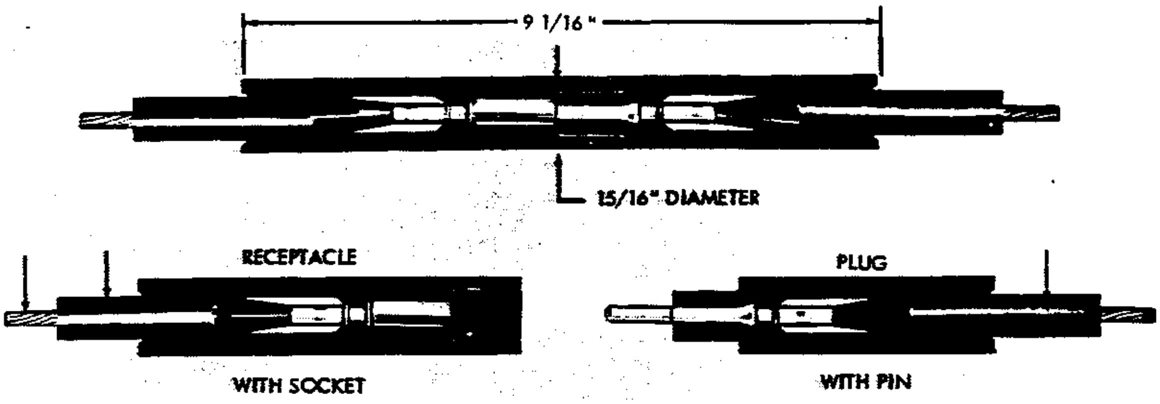


Figure 5-17. Direct-Earth-Burial Cable Connector.

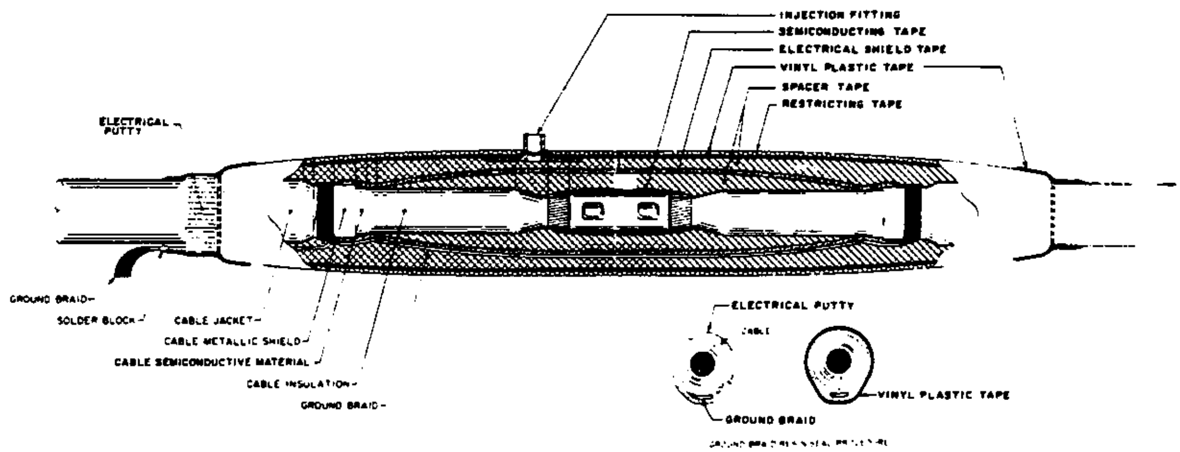


Figure 5-19. Pressure Splice For Shielded 5KV Cable.

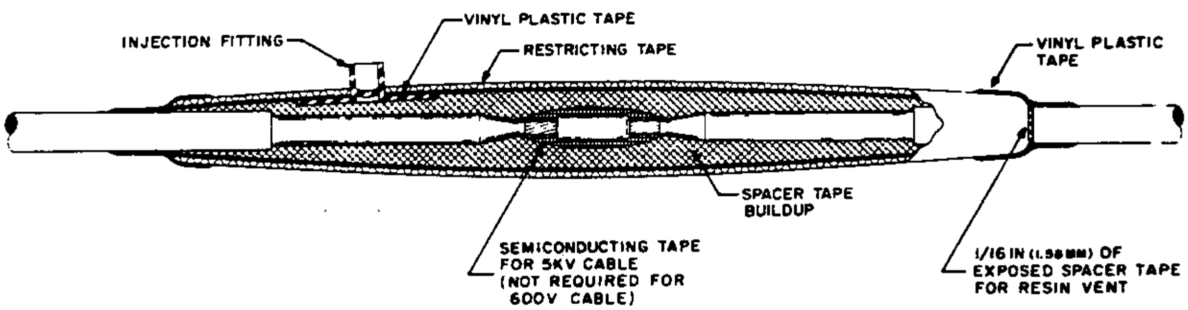
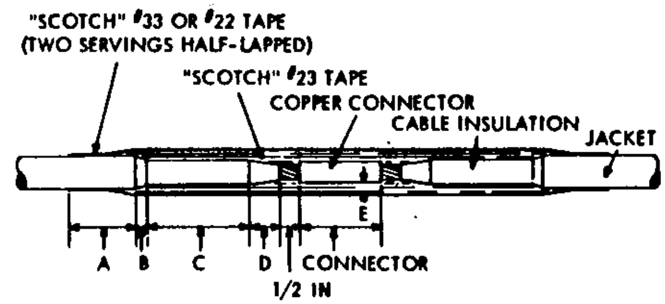


Figure 5-20. Pressure Splice For 600V and 5KV Unshielded Cable.

	CABLE SIZE	DIMENSIONS A	B 64THS	C 64THS	D 64THS	E 64THS	MATERIALS REQUIRED ROLLS OF #23 TAPE	FEET OF 3/4" #22 OR #33
600 VOLTS AND LOWER	#6 AWG	1 1/2"	8	80	16	6	.15	8
	#4 "	1 1/2"	8	80	16	6	.16	10
	#2 "	1 1/2"	8	80	16	6	.18	10
	#1 "	1 1/2"	12	100	20	8	.2	12
	1/0 "	1 1/2"	12	100	20	8	.22	12
	2/0 "	1 1/2"	12	100	20	8	.23	14
	3/0 "	1 1/2"	12	100	20	8	.24	14
	4/0 "	1 1/2"	12	100	20	8	.25	14
	250 MCM	1 1/2"	16	120	24	9	.27	16
	300 "	1 1/2"	16	120	24	9	.28	16
	350 "	1 1/2"	16	120	24	9	.30	18
	400 "	1 1/2"	16	120	24	9	.32	18
	500 "	1 1/2"	16	120	24	9	.34	20
	600 "	1 1/2"	16	140	28	10	.36	20
	700 "	1 1/2"	16	140	28	10	.38	22
	750 "	1 1/2"	16	140	28	10	.40	22
	800 "	1 1/2"	16	140	28	10	.41	24
	900 "	1 1/2"	16	140	28	10	.43	24
	1000 "	1 1/2"	16	140	28	10	.44	26
	1250 "	1 1/2"	20	160	32	12	.48	26
	1500 "	1 1/2"	20	160	32	12	.51	28
	1750 "	1 1/2"	20	160	32	12	.54	28
	2000 "	1 1/2"	20	160	32	12	.57	30
600 VOLTS TO 5,000 VOLTS	#6 AWG	2"	8	200	40	15	.5	16
	#4 "	2"	8	200	40	15	.55	18
	#2 "	2"	12	200	40	15	.62	20
	#1 "	2"	12	200	40	15	.67	20
	1/0 "	2"	12	200	40	15	.72	22
	2/0 "	2"	12	200	40	15	.82	22
	3/0 "	2"	12	200	40	15	.9	24
	4/0 "	2"	16	200	40	15	.94	26
	250 MCM	2"	16	220	44	17	1.1	28
	300 "	2"	16	220	44	17	1.2	30
	350 "	2"	16	220	44	17	1.3	32
	400 "	2"	16	220	44	17	1.35	34
	500 "	2"	16	220	44	17	1.45	34
	600 "	2"	16	220	44	17	1.5	36
	700 "	2"	16	220	44	17	1.6	38
	750 "	2"	16	220	44	17	1.75	38
	800 "	2"	16	220	44	17	1.85	40
	900 "	2"	16	220	44	17	1.9	42
	1000 "	2"	16	220	44	17	2.0	44
	1250 "	2"	20	240	48	18	2.2	46
	1500 "	2"	20	240	48	18	2.35	50
	1750 "	2"	20	240	48	18	2.5	52
	2000 "	2"	20	240	48	18	2.8	54



NOTE: THESE RECOMMENDATIONS ARE BASED ON SMOOTH, CONFORMING CONNECTORS OF THE SOLDER-SLEEVE, OR SMOOTH MECHANICALLY COMPRESSED TYPES. OTHER CONNECTORS HAVING IRREGULAR SHAPES, OR WITH PROJECTIONS OR SHARP EDGES SHOULD BE AVOIDED.

RECOMMENDED PROCEDURE

1. Train cables in final position and cut to proper length so cable ends will butt squarely.

2. Remove cable jacket from ends to be spliced for a distance equal to "C" plus "D" plus 1/2" plus one-half the length of the connector to be used. Determine dimensions to be used from the table on the drawing opposite the size of the conductor being spliced.

3. Remove the cable insulation from the ends of each conductor for a distance of 1/2" plus one-half the length of the connector.

4. Taper the insulation at each end smoothly for a distance equal to dimension "D" from the table opposite the cable size. Sandpaper may be used to buff taper to insure a smooth taper so that no voids will remain after the joint is insulated.

5. Taper cable jacket at each end smoothly for a distance equal to dimension "B". Sandpaper may be used to buff the tapers.

6. Join the conductors with the connector. If solder type connector is used, protect cable insulation with asbestos roving or cotton tape. Remove burrs.

7. Clean all exposed surfaces to be taped thoroughly with a knife. Wipe clean with a clean cloth.

8. Wrap successive layers of "SCOTCH" #23 tape half-lapped to dimension "A" beyond the shoulder of each jacket taper building up the splice smoothly with equal tension. Apply #23 Tape stretching it to reduce it to three-fourths of its original width to give proper elongation. Build the splice up equal to dimension "E" over the connector.

9. Cover the entire splice with two layers of "SCOTCH" #22 or #33 Tape half-lapped extending along cable jacket equal to dimension "A" per drawing. Tape should be stretched to reduce it 3/4" width to 5/8" to insure good conformance.

Figure 5-18. Dry Splice For Direct-Earth-Burial Cable.

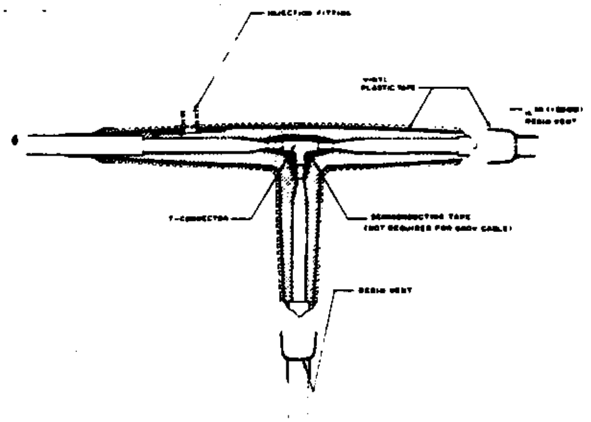


Figure 5-21. Pressure Tee Splice For 600V and 5KV Unshielded Cable.

manufacturers instructions for further details. When splicing a 600V conductor, it is not necessary to cover the connector with semiconducting tape as shown by the figure.

(e) **Pressure Resin Wye-Splice, 600V and 5kV, Single-Conductor, Unshielded Cable.** Figure 5-22 shows the construction of this splice. Splice dimensions and splicing instructions are furnished with the splice kit. When splicing a 600V conductor, it is not necessary to cover the connector with semiconducting tape as shown by the figure.

(f) **In-Line Dry Splice, 600V, Multiconductor Armored Cable.** Figure 5-23 shows the construction of this splice. Pencil the insulation at an angle of 45° to 60° to the axis of the conductor. Stagger the connectors if more than two conductors are to be spliced. Cover the connectors with high-voltage rubber tape to a thickness of 1½ to 2 times the thickness of the * conductor insulation. Apply two half-lapped layers of high voltage splicing tape over the bundled conductors, extending it between the ends of the cable inner jacket. Apply additional layers of rubber splicing tape, extended to cover the inner jacket. Solder electrical * grounding braid to the armor on both sides of the splice. Fill the grounding braid with solder to prevent moisture from entering the splice through the braid that extends outside the finished splice. The grounding braid outside the splice should be as long as required and should be anchored to the outer jacket with four layers of vinyl tape. Cover the splice bundle and grounding braid with four half-lapped layers of vinyl tape. Extend the vinyl tape at least 3 inches (7.62cm) beyond the splice on the cleaned outer jacket. Apply a liquid electrical coating, Scotchkote or equal, to complete the dry splice.

(g) **In-line Pressure Resin Splice, 600V and 5kV, Multiconductor Armored Cable.** Figure 5-24 shows the construction of this splice. Pencil the insulation at a 45° to 60° angle and stagger each connector. Wrap one layer of high-voltage rubber tape over each connector for 600V cable. Wrap semiconducting tape over each connector and extend it 1/16 inch (1.58mm)

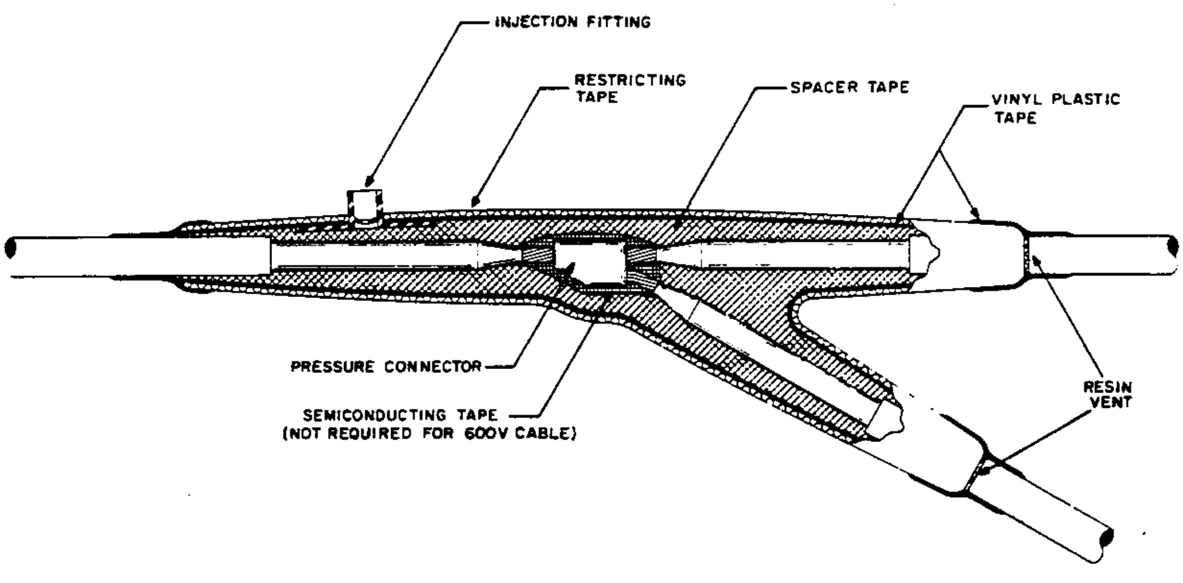
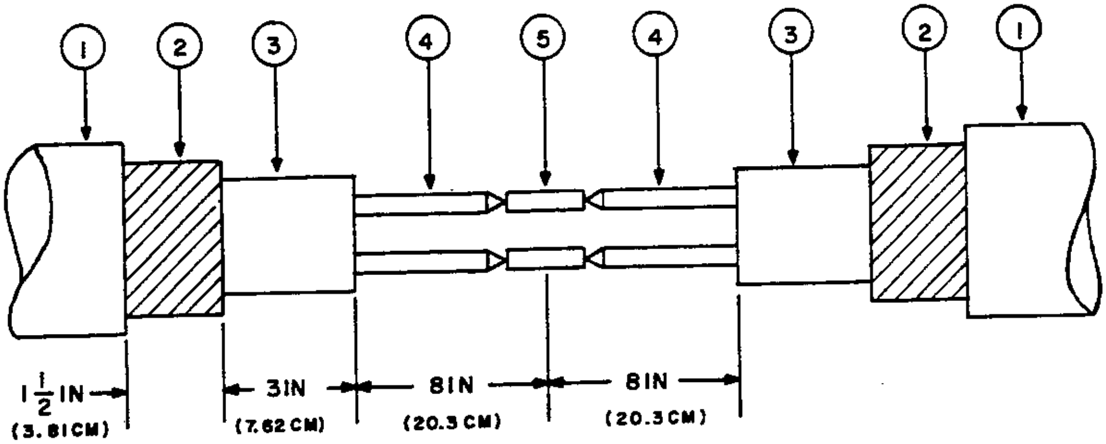


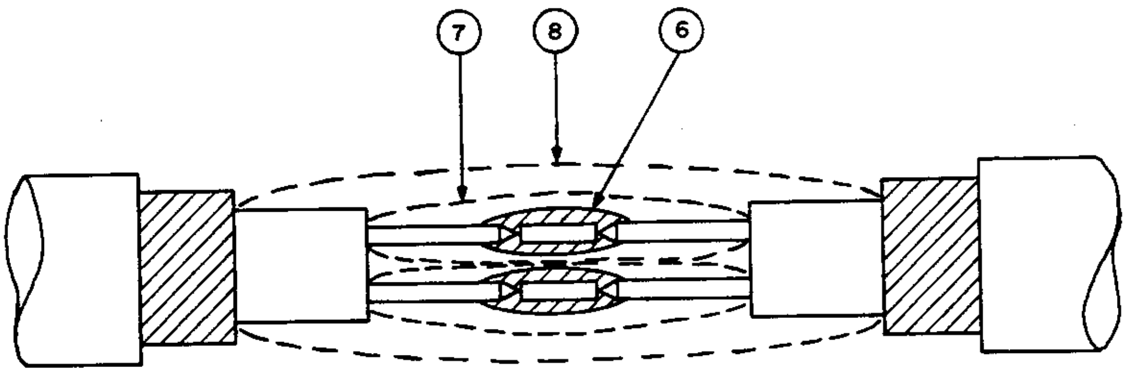
Figure 5-22. Pressure Wye Splice For 600V and 5KV Unshielded Cable.

STEP 1.



1 OUTER JACKET
2 STEEL ARMOR TAPE
3 INNER JACKET
4 CONDUCTOR INSULATION (PENCILLED)
5 CONDUCTOR CONNECTOR

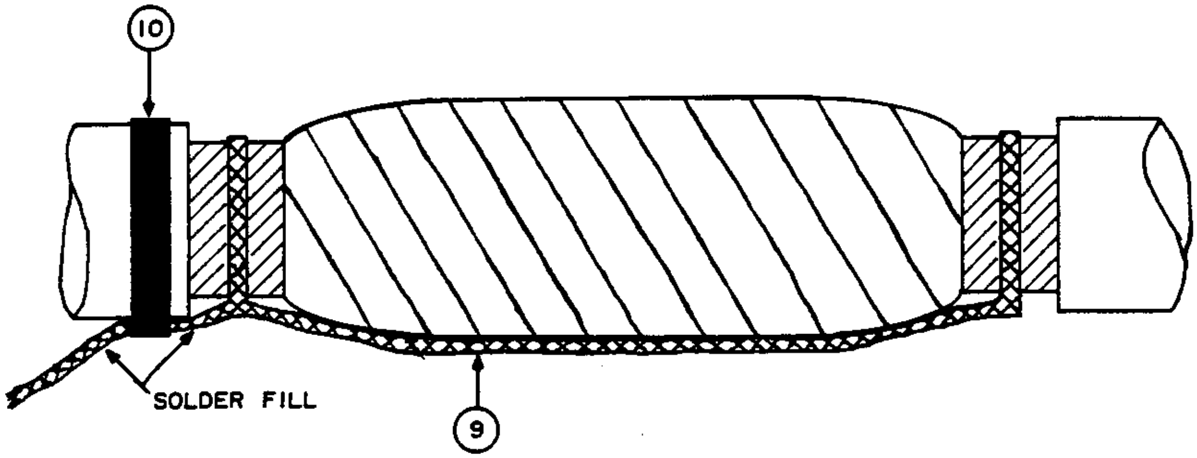
STEP 2.



6 RUBBER BASED HIGH VOLTAGE SPLICING TAPE
7 2 LAYERS, 1/2 LAPPED SPACER TAPE
8 2 LAYERS, 1/2 LAPPED SPACER TAPE

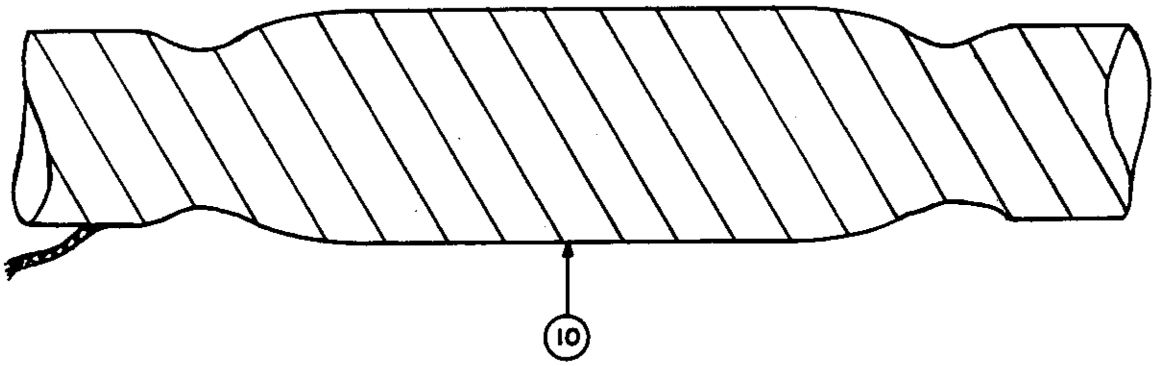
Figure 5-23. Dry Splice For DEB Armored 600V Multiconductor Cable.

STEP 3.



9 ELECTRICAL GROUNDING BRAID SOLDERED TO ARMOR
10 VINYL PLASTIC TAPE BRAID ANCHOR

STEP 4.



10 4 LAYERS, 1/2 LAPPED, VINYL PLASTIC TAPE WITH LIQUID ELECTRICAL COATING APPLIED.

Figure 5-23. Dry Splice For DEB Armored 600V Multiconductor Cable — continued.

over the end of the penciled area of 5kV conductor insulation. Cover each connector with three to four layers of screen spacer tape. Anchor the spacer tape with a small piece of vinyl tape. Cut off the armor tapes as shown in figure 5-24, step 2. Radiator hose clamps can be used to clamp the armor tapes prior to cutting. Cover the spliced bundle of conductors with two half-lapped layers of screen spacer tape. Cover the splice bundle with one half-lapped layer of electrical shielding tape soldered to the armor on both sides of the splice. Solder electrical grounding braid to the armor on one side of the splice for grounding purposes. Extend at least two sections of grounding braid across the splice and solder them to the armor. Wrap one layer of electrical putty tape around the cleaned outer jacket and embed the solder-filled portion of the grounding braid in the putty. Wrap two more layers of putty to hold the braid. Use screen spacer tape to cover the shielding tape and grounding braid as shown in figure 5-24, step 4. Extend the screen spacer tape to cover at least 3 inches (9.62cm) of cleaned outer jacket; extend tape at least 1 inch (2.54cm) beyond the electrical putty-tape resin dam. Apply layers of spacer tape to build the splice body diameter 1½ to 2 times the diameter of the cable. Place the injection fitting near one end of the splice body and anchor with vinyl tape. Apply two half-lapped layers of vinyl tape over the splice body, leaving a resin vent at each end, as shown. Apply two half-lapped layers of restricting tape over the vinyl tape, leaving the resin vents open. Inject resin into the splice. After the resin has hardened, the restricting tape, vinyl tape, and injection fitting may be removed.

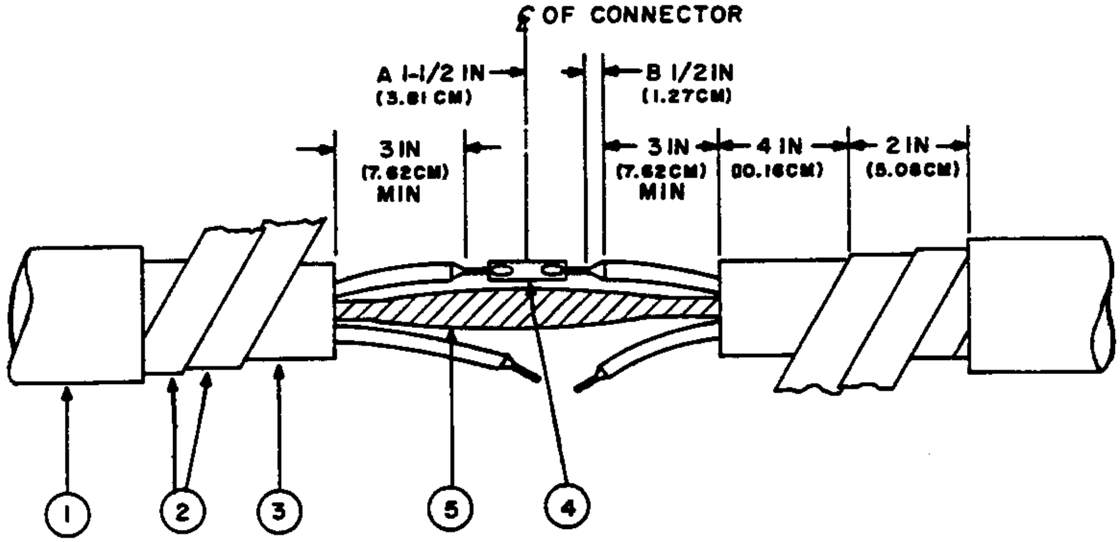
(h) **In-line Pressure Resin Splice, 600V and 5kV, Armored Cable.** Use this method when the outer jacket covering the cable armor is made of a porous material that may allow moisture penetration. Figure 5-25 shows the construction of this splice. Remove but do not cut off the armor. (See figure 5-25, step 1). The armor on each cable end may be held with a hose clamp during the splicing operation. The armor may be bent back over a hose clamp and taped to the cable to prevent interference during splicing. See figure 5-24, step 1, for typical splice dimensions. Insulation penciling, connector taping, screen spacer taping over the bundled conductors and shielding tape, and applying the grounding braid should be similar to figure 5-24, steps 1, 2, and 3, except that the electrical putty tape resin dam is not required. Apply spacer tape over the shielding braid and grounding braid to build up the center of the splice body to 1½ to 2 times the diameter of the cable. Wrap the armor tapes loosely over the splice body, and bolt their ends together with a grounding wire attached. Anchor the grounding wire with four wraps of vinyl tape. Use two half-lapped layers of screen spacer tape to cover the armor, grounding wire, and grounding wire anchor. Extend the layers of spacer tape at least 3 inches (9.62cm) beyond the splice to cover the ends of the outer jacket. Attach an injection fitting near one end of the splice body with vinyl tape. Cover the splice body with two half-lapped layers of vinyl tape, leaving a resin vent open at each end of the splice body as shown. Apply two half-lapped layers of restricting tape over the vinyl tape, leaving the vents open. After the injected resin has harden, the restricting tape, vinyl tape, and injection nozzle may be removed from the splice.

(i) **In-line Pressure Splice, 600V and 5kV, Multiconductor, Armored Cable.** This splice, shown by figure 5-26, is similar in construction to the splice
* shown by figure 5-24. This splice is used for XLP (cross-linked polyethylene) insulated cable, subject to heavy currents and high temperatures. Semiconducting tape should be used over the connector and over the edge of the insulation. The connectors need not be wrapped with semiconducting tape when splicing XLP-insulated 600V cable. The following details apply *
to this splice after the cable ends have been prepared.

1 Install a crimp connector on each conductor. Stagger the connectors if more than two connectors are to be connected.

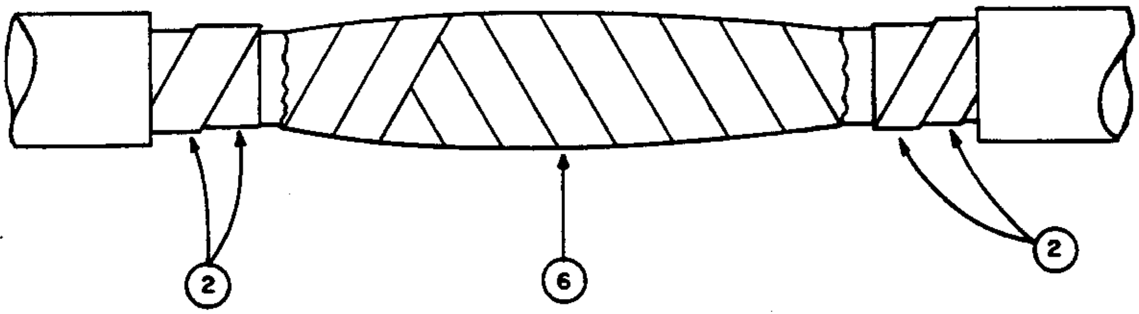
2 Wrap each connector with two layers of highly elongated semiconducting tape, and fill in between the ends of each connector and the ends of the insulation. Connectors for 600V insulated conductors may remain bare, and the space between the ends of the connector and the ends of the insulation does not have to be filled with tape.

STEP 1.



(1) OUTER JACKET
(2) ARMOR, TWO TAPES
(3) INNER JACKET
(4) TYPICAL STAGGERED CONDUCTOR CONNECTOR
(5) THREE TO FOUR 1/2 LAPPED LAYERS OF SCREEN SPACER TAPE

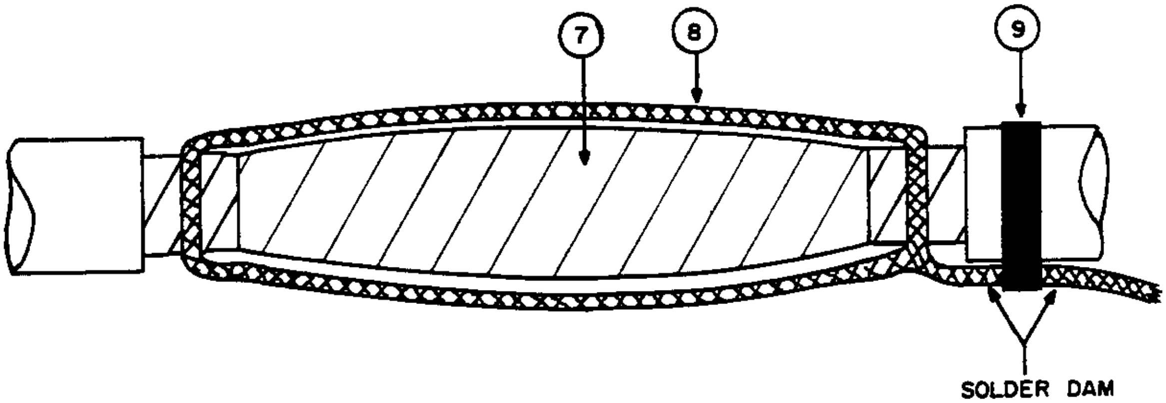
STEP 2.



(2) ARMOR, TWO TAPES CUT OFF
(6) TWO 1/2 LAPPED LAYERS OF SPACER TAPE

Figure 5-24. Pressure Splice For 600V to 5KV Multiconductor Armored Cable.

STEP 3.

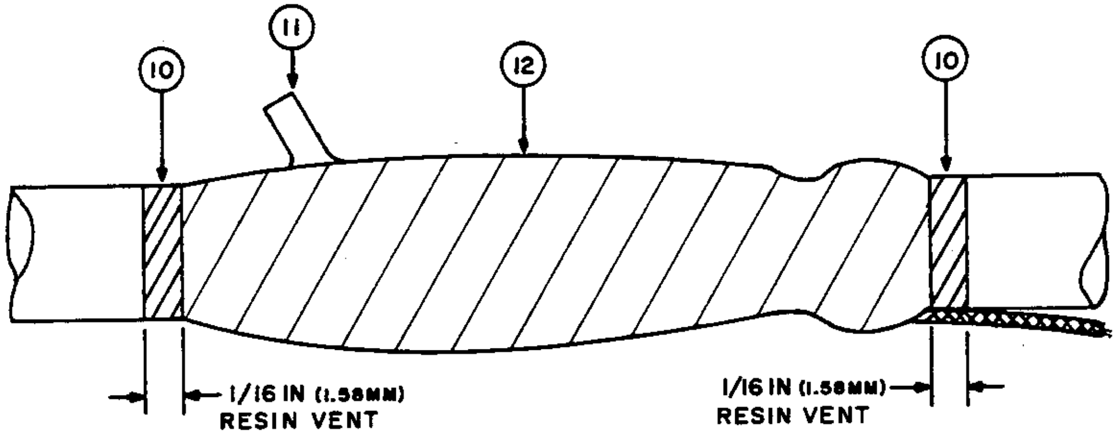


* (7) 2 LAYERS, 1/2 LAPPED RUBBER SPLICING TAPE *

(8) ELECTRICAL GROUNDING BRAID

(9) ELECTRICAL PUTTY RESIN DAM

STEP 4.



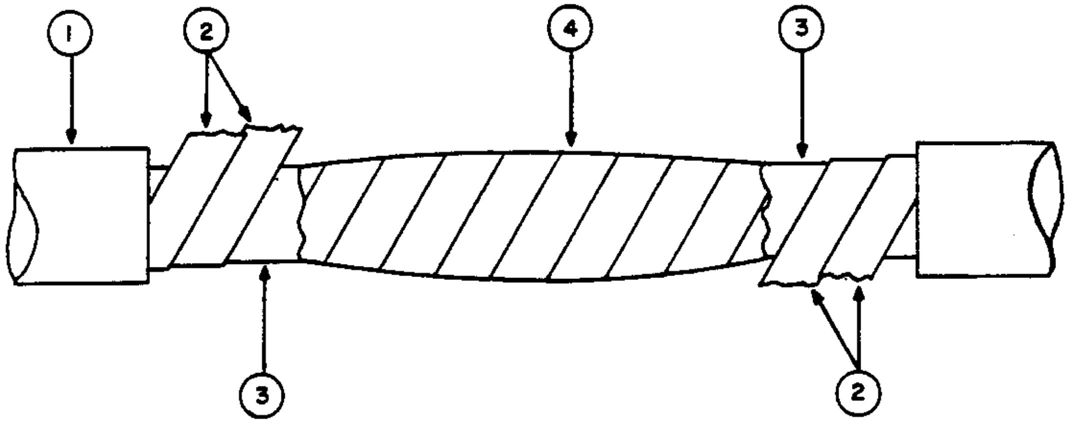
(10) SPACER TAPE

(11) INJECTION FITTING

(12) VINYL TAPE

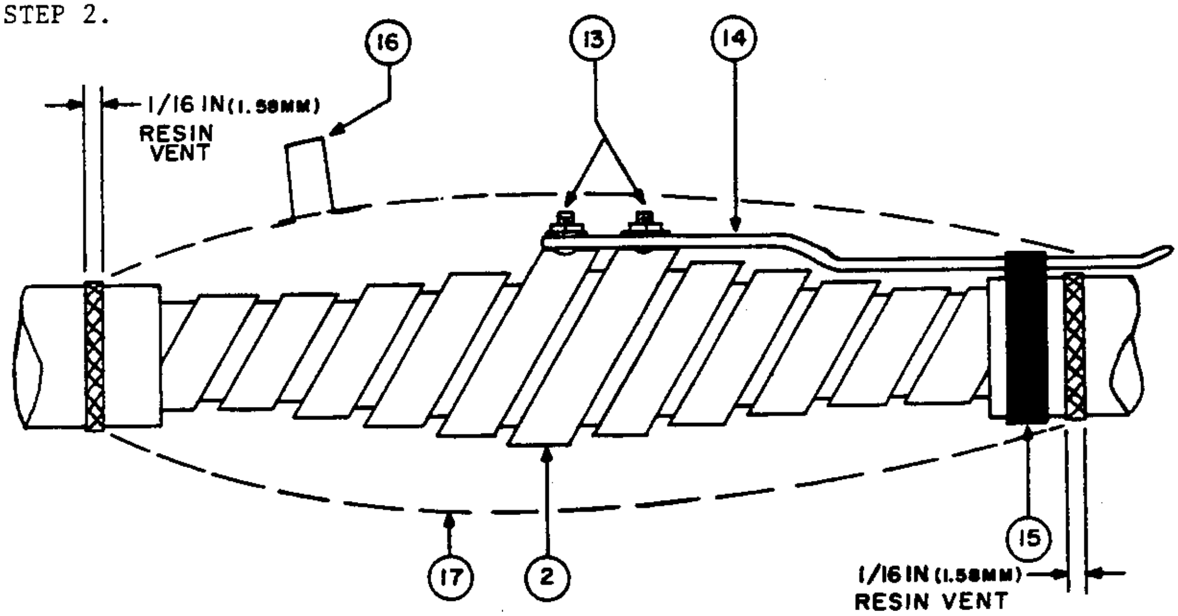
Figure 5-24. Pressure Splice For 600V to 5KV Multiconductor Armored Cable — continued.

STEP 1.



(1) POROUS OUTER JACKET
(2) ARMOR, TWO TAPES
(3) INNER JACKET
(4) SPACER TAPE

STEP 2.



(2) ARMOR
(13) BOLT, WASHERS AND NUT
(14) NO. 8 OR NO. 10 BARE COPPER GROUNDING WIRE.
(15) VINYL TAPE ANCHOR
(16) INJECTION FITTING
(17) SPACER TAPE, COVERED WITH VINYL TAPE AND RESTRICTING TAPE

Figure 5-25. Partial Pressure Splice For 600V to 5KV Multiconductor Armored Cable.

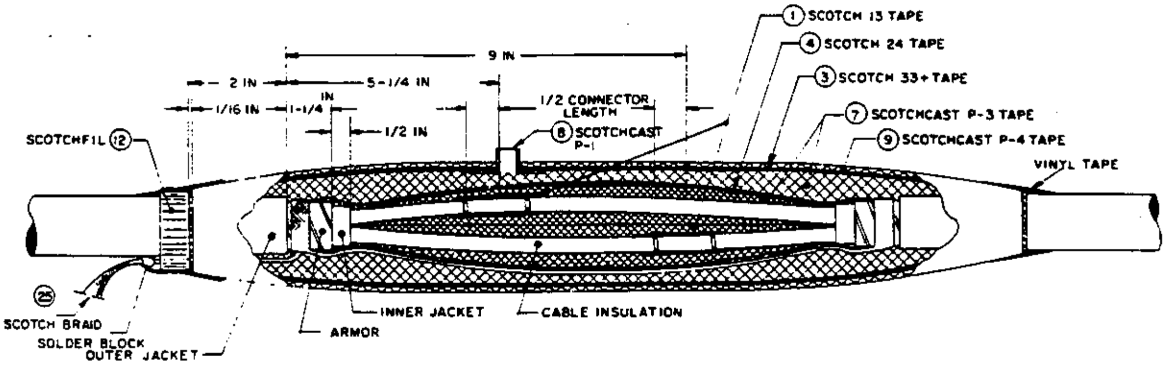


Figure 5-26. Pressure Splice For 5KV Cross-Linked Polyethylene-Insulated, Multiconductor, Armored Cable.

3 Wrap screen spacer tape over the individual conductor insulation, tapering gradually toward the inner jacket. Build up tape on each conductor to a ¼ inch (.635cm) thickness at the center of the splice.

4 Wrap one half-lapped layer of electrical shielding tape around entire bundle, ending ½ inch (1.27cm) onto armor. Solder the ends of the electrical shielding tape.

5 Attach ground braid as shown and solder to the armor.

6 If the splice is to be grounded, solder-block the grounding braid. Wrap one layer of electrical putty tape around the outer jacket. Press the solder block into the layer of putty tape. Wrap two layers of electrical putty tape over the solder block and the first layer of putty tape to complete the moisture dam.

7 Wrap four half-lapped layers of screen spacer tape over the entire splice (moisture dam not included), extending 2 inches (5.08cm) onto clean cable jacket and tapering gradually toward the jacket.

8 Position the injection fitting as shown in figure 5-26 and wrap the entire splice with two half-lapped layers of vinyl tape. Leave 1/16 inch (1.58mm) of spacer tape exposed at the ends of the splice body to permit venting of the resin.

9 Wrap two half-lapped layers of restricting tape over the vinyl tape. Do not cover the resin vents.

10 When resin appears at each vent during injection, cover each vent and the moisture dam with several layers of vinyl tape.

e. Control and Telephone-Type Cable Splicing.

(1) Control and Telephone-Type Cable Splice Preparation.

(a) Cut Cable Ends. Cut the end of the cables off square. If the cable has been destroyed because of overvoltage or overcurrent at the fault location, remove damaged portions from each end of the cable. If adequate cable slack is not available to make the splice, install a section of new cable by making two splices. If the cable is direct-earth buried, install enough cable to bridge the gap, plus 3 feet (0.91 meter) of new cable to form a loop.

(b) Determine Cable End Overlap. Cable end overlapping is performed by first arranging the cut ends of the cables to face each other. Overlap the cable ends as recommended by the splice manufacturer. Cable overlap is required in order to stagger the conductor connectors. Figure 5-28 shows a typical multiconductor splice. Dimension A shows the conductor splice area, within which the cable splice is to be made by staggering the conductor connectors. Conductor connectors should be as recommended by the splice manufacturer to ensure compatibility of materials and dimensional mold fits. After overlapping the ends of the cable, the cables should be held or clamped in position to maintain the overlap during the splicing procedure.

(c) **Outer Jacket Removal.** Remove the outer jacket from the ends of the cables to be spliced. Use a sharp knife or cable stripping tool to score the outer jacket to a depth of approximately one-half its thickness. If the jacket cannot be removed, carefully cut through the jacket, using care not to nick the armor, shield, or conductor insulation. The length of the jacket to be removed will depend upon the type of splice kit selected. Since a single-pair cable splice, such as shown by figure 5-27, does not require overlapping the cable ends, the amount of outer jacket to be removed is as shown in figure 5-27. The amount of outer jacket to be removed from a cable having from 3 to 202 conductors may be determined from step 1 of figure 5-28. If the cable conductors are to be spliced with in-line crimp connectors, the dimension for the outer jacket to be removed from each end of the cable is equal to dimension C (for conductor overlap), plus dimension B, plus dimension A. If the cable conductors are to be spliced with communications type connectors, add 2 inches (5.08cm) to dimension C.

(d) **Outer Jacket Cleaning.** Clean and throughly scuff the outer jackets for 6 inches (15.2cm) with abrasive cloth to remove all dirt, wax, and extrusion marks. Cover the cleaned area with vinyl tape for protection during splicing.

(e) **Armor Removal.** Remove the armor from the ends of all control and telephone-type cables to be spliced. If the cable diameter is large enough, place an adjustable hose clamp over the armor with an edge, nearest the end of the cable, at the location where the cable is to be cut. Tighten the clamp and score the armor with a hacksaw blade near the edge of the clamp. Unwrap the armor tape(s) and break off. Leave the clamp on the armor until it has to be removed to rebuild the armor over the splice. If the cable armor is too small to use a hose clamp, wrap several layers of vinyl tape around the armor with the edge of the tape wrap nearest the cable end at the location where the armor is to be cut off. Score the armor with a hacksaw blade. Unwrap the armor and break off. Leave the tape in place until it has to be removed during the splice buildup.

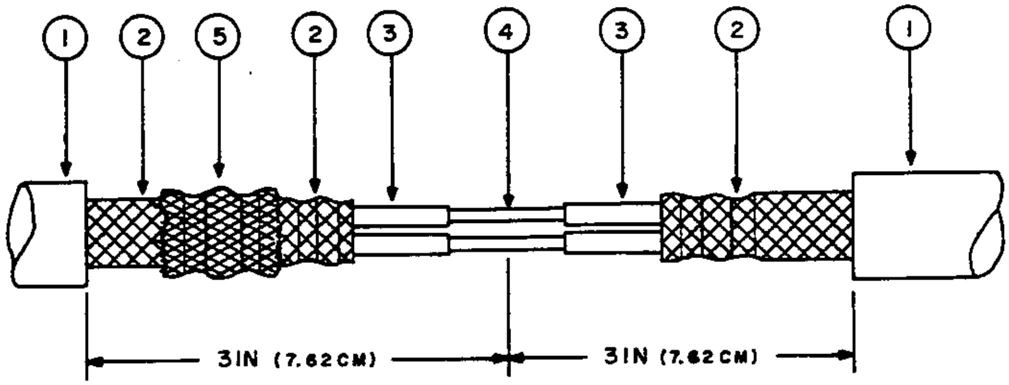
(f) **Shield Removal.**

1 **Overall Cable Shield.** After removal of the outer jacket, remove the taped or corrugated overall shield from the splice area. If the cable diameter is large enough, place an adjustable hose clamp over the shield with its edge nearest the cable end at the location where the shield is to be cut. Tighten the clamp. Score the shield with a hacksaw blade near the edge of the clamp nearest the cable end. Unwrap the taped shield and break off. Corrugated shield may be unrolled from the cable and broken apart at the scored mark with needle-nose pliers. If the cable diameter is too small to use a cable clamp, use several layers of vinyl tape to bind the shield for scoring and removal. Remove core wrapper and any filler materials leaving 3/4 inch (1.9cm) exposed beyond cable jacket. See figure 5-27.

2 **Pair Shielding.** Remove aluminum backed mylar or braided copper wire pair shielding as required by the splice. One layer of vinyl tape may be wrapped around the end of an aluminum-mylar shield to hold it in place. The copper drain wire of the aluminum-mylar shield should be folded back over the cable and taped to prevent interference during splicing. The copper drain wire must be used to establish shield continuity during splice buildup, as shown by figure 5-29, step 2. Layers of vinyl tape may be used to hold braided wire pair shielding in place before and after removal of excess shielding with scissors or cutting pliers. Some splice operations require that the braided shielding be expanded and pushed back on the cable end and remain uncut until required to rebuild the shield over the splice, as shown by figure 5-27, step 1.

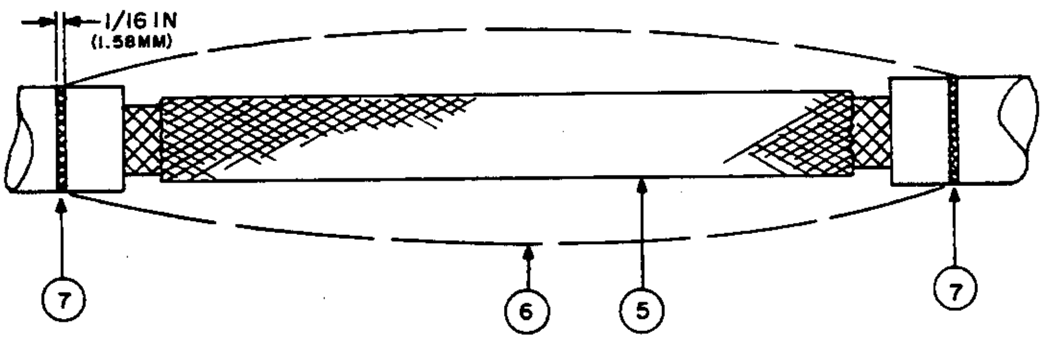
(g) **Inner Jacket Removal.** Some cables have an inner jacket between the overall cable shield and the conductors. A typical cable is shown by figure 5-30, step 1. Remove the inner jacket by scoring and cutting with a knife, leaving 1 inch (2.54cm) of inner jacket exposed. Use care to not cut the insulation of the conductors. Throughly scuff inner jacket with abrasive provided.

STEP 1.



1 OUTER JACKET
2 BRAIDED CONDUCTOR PAIR SHIELD (PUSHED BACK TO COMPRESS BEFORE SPLICING CONDUCTORS; STRETCH OVER CONNECTORS AFTER SPLICING)
3 INSULATED CONDUCTOR
4 INSULATED IN-LINE COMPRESSION SPLICE
5 BRAIDED, TINNED COPPER SHIELDING (COMPRESSED)

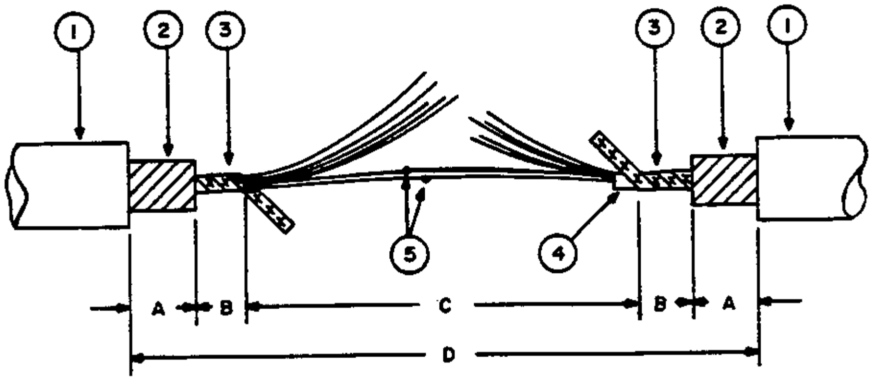
STEP 2.



5 BRAIDED, TINNED COPPER SHIELDING
6 TAPED DRY SPLICE, OR PRESSURE OR POURED RESIN SPLICE SPLICE BODY
7 VENT FOR PRESSURE SPLICE

Figure 5-27. Pressure or Poured Splice For Braid-Shielded Pair, Control or Telephone-Type Cable.

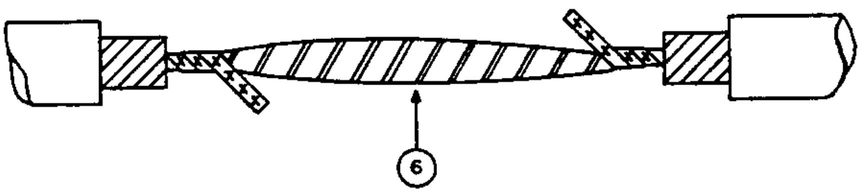
STEP 1.



1 OUTER JACKET
2 ARMOR TAPE, CUT OFF
3 OVERALL SHIELD, ALUMINUM TAPE
4 INNER JACKET
5 IN-LINE OR COMMUNICATION TYPE INSULATED COMPRESSION CONNECTOR (STAGGERED)

UNSHIELDED PAIRS/CONDUCTORS	A	B	C	D
11/26	3/4 IN (1.9CM)	½ IN (1.27CM)	3½ IN (15.24CM)	6 IN (15.24CM)
27/54	1 IN (2.54CM)	½ IN (1.27CM)	7 IN (22.8CM)	10 IN (25.4CM)
51/102	1 IN (2.54CM)	1 IN (2.54CM)	12 IN (30.48CM)	16 IN (40.6CM)
101/202	1 IN (2.54CM)	1 IN (2.54CM)	18 IN (45.7CM)	22 IN (55.9CM)

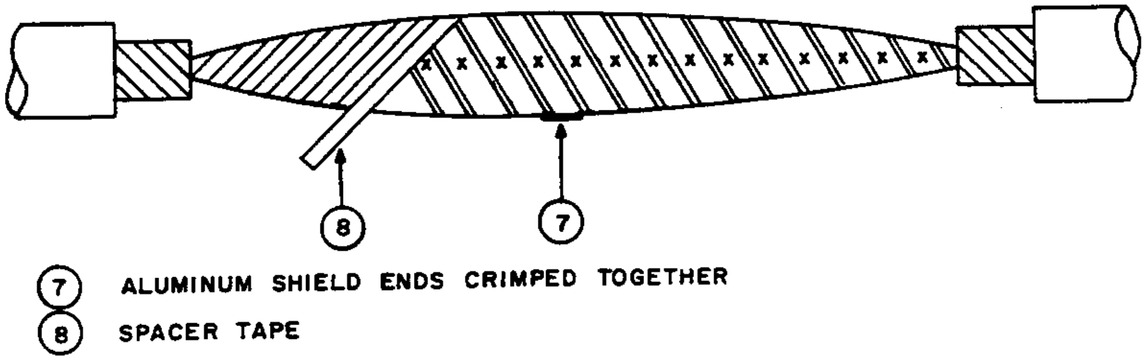
STEP 2.



6 SPACER TAPE, 1 LAYER (NOT LAPPED)

Figure 5-28. Pressure Splice For Multiconductor, Shielded and Armored, Control or Telephone-Type Cable.

STEP 3.



STEP 4.

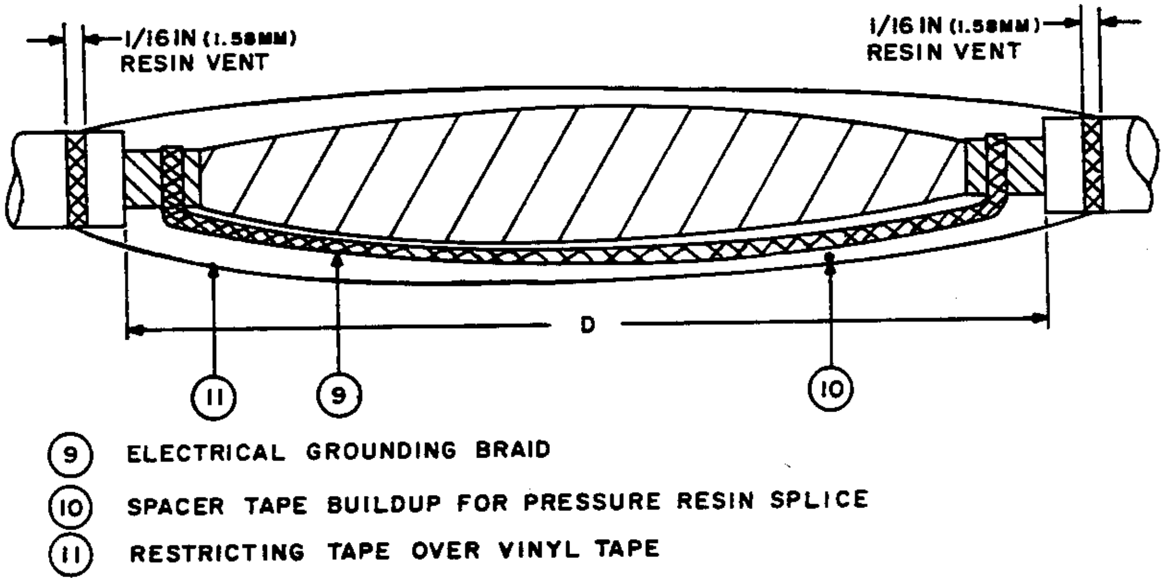
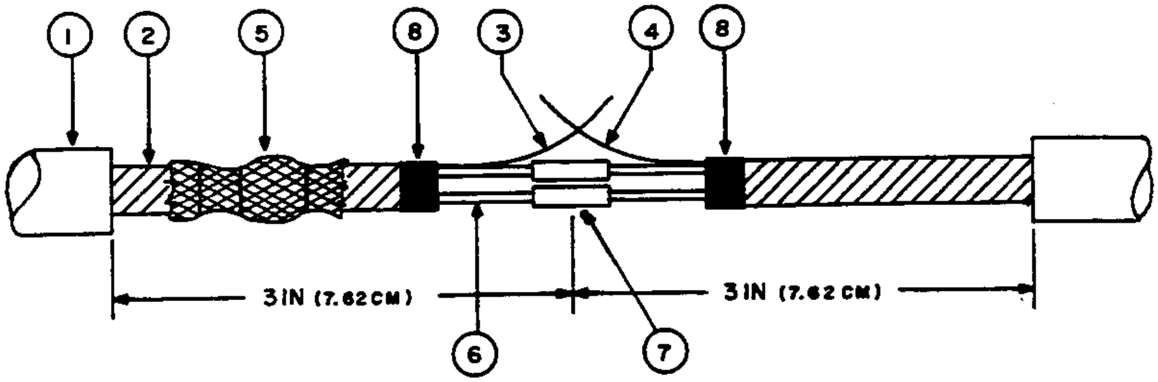


Figure 5-28. Pressure Splice For Multiconductor, Shielded and Armored, Control or Telephone-Type Cable — continued.

STEP 1.



1 OUTER JACKET

2 MYLAR BACKED, ALUMINUM FOIL SHIELD TAPE

3 4 COPPER DRAIN WIRE (PART OF SHIELD TAPE)

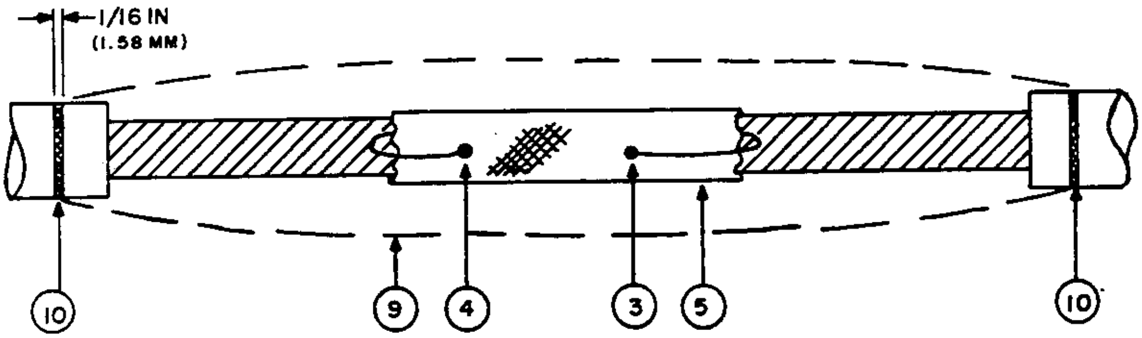
5 BRAIDED, TINNED COPPER SHIELDING (COMPRESSED)

6 CONDUCTOR INSULATION

7 INSULATED COMPRESSION SPLICE

8 VINYL PLASTIC TAPE

STEP 2.



3 COPPER DRAIN WIRE FROM LEFT SIDE SHIELD, SOLDERED TO SHIELDING

4 COPPER DRAIN WIRE FROM RIGHT SIDE SHIELD, SOLDERED TO SHIELDING

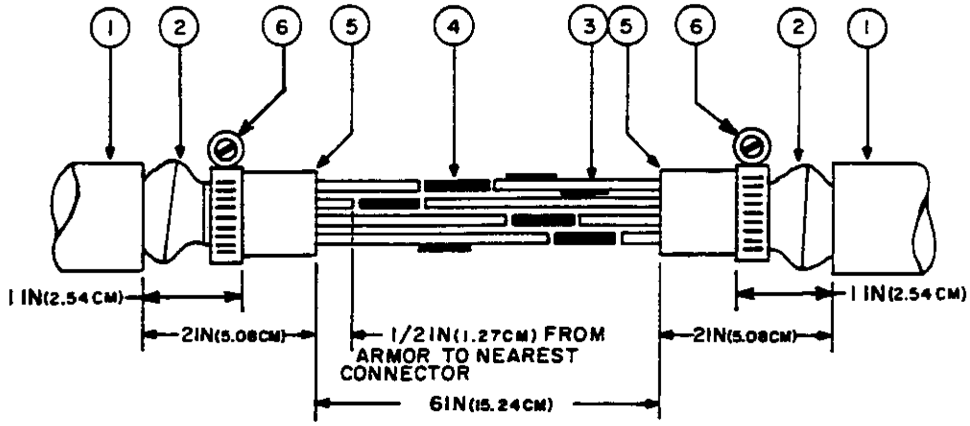
5 BRAIDED, TINNED COPPER SHIELDING

9 TAPED DRY SPLICE OR PRESSURE OR POURED RESIN SPLICE

10 VENT FOR PRESSURE SPLICE ONLY

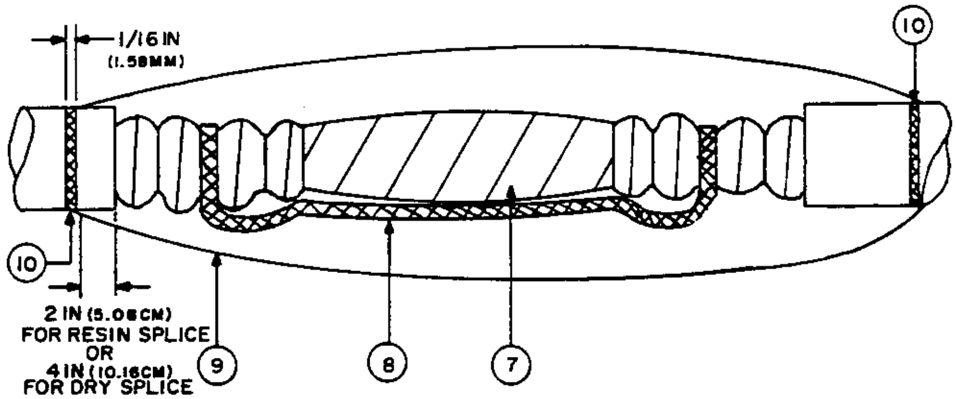
Figure 5-29. Pressure or Poured Splice, Foil Shielded Pair, Control or Telephone-Type Cable.

STEP 1.



1. OUTER JACKET
2. NONFERROUS ARMOR, CORRUGATED OR TAPE
3. INSULATED CONDUCTOR
4. INSULATED IN-LINE CONDUCTOR SPLICE
5. INNER JACKET OR FILLER TAPE
6. ADJUSTABLE HOSE CLAMP

STEP 2.



7. CONDUCTORS BUNDLED WITH VINYL PLASTIC TAPE (FOR DRY SPLICE) OR WITH 2 LAYERS SPACER TAPE (FOR RESIN PRESSURE SPLICE)
8. ELECTRICAL GROUNDING BRAID
9. SPLICE BODY BUILDUP
10. VENT FOR PRESSURE SPLICE

Figure 5-30. Tape or Pressure Splice, Multiconductor, Armored, Control or Telephone-Type Cable.

(h) **Nonshielded Cable** - Remove core wrapper and filler materials flush with jacket.

(i) **Insulation Removal.** Remove the insulation from the ends of conductors to be spliced with compression-type in-line connectors. The insulation should be removed with an insulation stripping tool to avoid nicking the conductor. The amount of insulation removed from each conductor end should be equal to one-half the length of the connector. If communication cable connectors are to be used for splicing, the conductors may be spliced without removing insulation.

(2) **Control and Telephone-Type Cable Splice Buildup.**

(a) **Conductor Connector Installation.** Cut conductors to desired length, staggering connections where possible to keep overall bundle to a minimum. Remove conductor insulation for one-half connector length. Be careful not to nick conductors. Do not remove conductor insulation if using a live spring self-stripping type connector such as the Scotchlok 500 series or equal. Install the proper size insulated butt connectors, such as the Scotchlok 42-400 or 42-500 series or equal, with the proper crimping tool.

<u>1</u> **Staggered In-line Splice Connector Installation.** Adjust the cable ends so that dimensions C and D of figure 5-28, step 1, will be correct for the splice to be made. Select an unpaired conductor or a conductor pair from one end of the cable. Select the same color unpaired conductor or same color conductor pair from the other cable end. Select the same color conductor if a pair is to be spliced. Cut off approximately one-half of each conductor end (one-half of dimension C if the conductors are properly overlapped). Strip the insulation from each conductor end and attach them together with an in-line connector, which now should be located at approximately the center of the splice area. Select another unpaired conductor or the other conductor of the first pair selected. Make the in-line splice either to the right or left of the first splice. The in-line connectors must not touch unless they are insulated. Select and splice the next unpaired conductor, or one conductor of a conductor pair, on the other side of the center connector. Alternate the conductor connectors progressively away from the connector located at the splice area center. After one row of staggered connectors occupies the length of the splice area (dimension C), start another row of connectors at the center of the splice. Stagger all connectors so that the splice body buildup over the bundled conductors will be symmetrical. A multiconductor cable with staggered connector may be taped or encapsulated.

<u>2</u> **Staggered Communications Type Connector Installation.** Adjust the cable ends so that dimension D (figure 5-28, step 1) will be correct for the splice to be made. Each conductor protruding from beneath the inner jacket (figure 5-28, step 1, or 5-30, step 1) should be equal in length to dimension C (figure 5-28, step 1) plus 2 inches (5.08cm) in order to make the splice properly. Select an unpaired conductor or both conductors of a conductor pair from one of the cable ends. Select an unpaired conductor of the same color or the conductor pair with the same colors from the other cable end. With excessive slack removed from both unpaired conductors or from both conductor pairs, twist them together two turns, with the twist located at approximately the center of the splice area. The two or the four conductor ends should be cut off 2 inches (5.08cm) from the twist. Without removing insulation from the ends of the conductors, push two conductors having the same color into the two holes of the communications type connector body for approximately ½ inch (1.27cm). The conductor ends can be seen through the clear plastic body of the communications type connector. Compress the connector with a compression tool or a pair of pliers. If a conductor pair is being spliced, connect the other two conductor ends, having the same color, with a communications type connector. Select the next unpaired conductor or conductor pair from both cable ends and make the twist approximately 2 inches (5.08cm) on either side of the first splice twist. Splice all the remaining unpaired conductors or conductor pairs, staggering the twists on each side of the center of the splice area, on 2-inch (5.08cm) centers. Stagger the splice twists for subsequent rows of splices. When all splices are complete, compress all connectors against the conductor bundle by bending all splices at their twisted area. Bend all connectors away from the center of the splice. Multiconductor cable splices made with communications type connectors must be covered with tape (dry splice) or encapsulated.

(b) **Tape Application Method.** Level wind all tapes used to build the splice body over the bundled conductors. Apply all tapes in half-lapped layers unless shown otherwise by the splice kit instructions.

(c) **Spacer Tape Application.** Use spacer tape to build up the splice body for pressure splices. The spacer tape should extend at least 3 inches (7.62cm) beyond the splice area into the cleaned cable outer jacket.

(d) **Moisture-Proof Tape Application.** Apply vinyl tape on the outside of a taped splice for waterproofing and to provide resistance to abrasion. Vinyl tape must be applied over the outside of the spacer tape body for a polyurethane compound pressure splice. The vinyl tape must cover the entire splice body, except for approximately 1/16 inch (1.58mm) to provide a polyurethane compound vent for each cable entering the splice. Vinyl tape should be used to anchor the injection fitting to the spacer tape body of a pressure splice.

(e) **Restricting Tape Application.** Apply restricting tape over the vinyl tape cover of the pressure splice body. The restricting tape is to cover all the vinyl tape, but must not cover the polyurethane compound vents.

(f) **Braided, Tinned Copper Shielding Application.** Use copper braid shielding to rebuild the shield of a cable, as shown by figures 5-27, step 1, and 5-29, step 1. Electrical shielding tape should not be used for this application because it cannot be compressed or stretched.

(g) **Electrical Grounding Braid Application.** Use electrical grounding braid to provide armor continuity across a splice, as shown by figures 5-28, step 4, and 5-30, step 2.

(h) **Polyurethane Compound In-line Pressure Splice Application.**

1 **Insulation Preparation.** Strip the insulation from the ends of the conductors when spliced with compression type in-line connectors. Communications type connectors may be used to splice small conductors without stripping insulation from the ends of the conductors. All connectors should be staggered. The insulation does not have to be penciled prior to connecting the ends of the conductors of communications and telephone-type cables with either type connector.

2 **Connector Insulation.** Insulate bare compression types of in-line connectors after connecting two conductors together. Insulate connectors with vinyl tape or with nonshrinkable or shrinkable tubing. If tubing is used, cut it to length and slide it over one of the conductors before connecting both conductor ends with a connector. Slide the tubing back over the connector after it has been compressed. Heat-shrink tubing should not be shrunk with an open flame unless the conductor insulation is protected on both sides of the connector.

3 **Conductor Pair Shielding.** Rebuild the shield covering a conductor pair splice in a manner shown by figure 5-27, step 2, and 5-29, step 2. Prior to splicing, a section of braided, tinned copper shielding should be slipped over the end of the cable on one side of the splice. The braided shielding section may be compressed to keep it out of the splice area. During the splicing operation, this section of shielding is used to cover any gap when joining the shields from both sides of the splice during the splicing operation.

4 **Multiconductor Cable Overall Shielding.** Figure 5-28, step 1, shows a multiconductor cable with an aluminum tape overall cable shield. Since the soldering of braided copper shielding to aluminum is difficult, the aluminum shielding tapes must be reused to shield the bundled conductors after splicing. The aluminum shielding tape on each side of the splice should be trimmed to approximately one-half its original width, so that the polyurethane compound will flow through to saturate the spacer tape underneath when making a pressure splice. If the ends of the aluminum tapes are to be connected by a bolt, washers, and nut, this hardware should be nickel or cadmium plated. Do not use copper or brass. If the ends of the aluminum tapes are crimped together, clean the ends with a rasp or aluminum oxide cloth and a cloth moistened by trichloroethane. Bend the ends of the aluminum tape to form the crimp, but put antioxidant grease in the crimp before compressing it with pliers. Wipe off the excess grease. If the overall cable shield is made of a metal that can be soldered, follow the same procedures above, temporarily holding the shield tape in place with vinyl tape and soldering the tape ends instead of crimping them together.

5 **Splice Body Buildup.** Figure 5-28, step 4, shows a conductor pair shielded cable splice that may be encapsulated by a pressure splice. Build up pressure-splice body with layers of screen spacer tape over the splice and onto the outer jacket of the cable. Extend final layers of the spacer tape at least 3 inches (7.62cm) on the cleaned and scraped outer jacket, beyond the splice area. The maximum diameter of the spacer tape splice body at the center of the splice should be 1½ to 2 times the diameter of the cable.

6 **Multiconductor Cable Armor.** Figure 5-28, step 4, shows a pressure splice with electrical grounding braid used to provide electrical continuity for the cable armor. Wrap the braid once around the armor on

both sides of the splice and solder. The grounding braid may be extended outside the splice body (not shown, but similar to figure 5-30, step 2) for grounding purposes. Build up the splice body to cover the putty or tape pressure dam and braid anchor (figure 5-30, step 2).

7 **Injection Fitting Location and Vinyl Plastic Tape.** The procedure for locating the injection fitting and covering the screen spacer tape splice body with vinyl tape is the same as outlined in subparagraph 58d(3)(d). A vent shall be formed on each end of the splice by leaving the spacer tape uncovered.

8 **Restricting Tape.** The procedure for covering the splice body is outlined in subparagraph 58d(3)(e). Care shall be exercised not to cover the splice body vents with restricting tape.

9 **Pressure Gun Preparation.** The pressure gun is prepared as outlined in subparagraph 58d(3)(f), except that polyurethane compound must be used to make pressure splices in control and telephone-type cables.

10 **Polyurethane Compound Injection.** The procedure for injecting this compound is the same as for injecting epoxy resin into a power cable pressure splice as outlined in subparagraph 58d(3)(g).

11 **Tape Removal.** After the polyurethane compound has hardened, the restricting tape, vinyl tape, and injection nozzle may be removed from the splice. Removal is not necessary for proper operation.

12 **Cable Use.** The cable may be energized after the compound has hardened.

(j) Polyurethane Compound Tee and Wye Pressure Splice Application.

1 **Unshielded, Unarmored Multiconductor Cable Splice.** Tee and wye pressure splices in unshielded and unarmored control and telephone-type cables can be made by using communications type connectors to join the three ends of the conductors to be spliced and by building a screen-spacer-tape body for a pressure splice.

2 **Shielded Pair Splice.** The individual shield covering a conductor pair should be rebuilt by wrapping electrical shielding tape over the conductors and communications type connectors, then soldering the shielding tape to the pair shields entering the splice. If the cable is constructed so that the pair shields are insulated from each other, wrap one to two layers of spacer tape over the electrical shielding tape used to splice the shield of each pair. Build up the screen spacer-tape-body to make a pressure splice. Extend the splice body at least 3 inches (7.62cm) onto the outer jackets of the cables entering the splice. Inject polyurethane compound into the splice.

3 **Paired or Unpaired Conductor Cable With Overall Shield.** A tee or wye pressure splice made in a cable with an overall shield should be made by first wrapping the bundled conductors and their staggered communications type connectors with at least two layers of screen spacer tape. Cut off the taped or corrugated overall cable shield not less than 1 inch (2.54cm) beyond the end of the outer jacket on each cable entering the splice. Shield the bundled and wrapped splice body by wrapping with one loosely half-lapped layer of electrical shielding tape. Wrap the shielding tape at least two turns around the shield on each cable end. Solder the shielding tape to the cable shields, unless the cable shields are made of aluminum. Wrap tightly without soldering if the cable shields are aluminum. Build up the splice body with screen spacer tape and encapsulate it with polyurethane compound.

4 **Shielded or Unshielded, Multiconductor or Paired Cable With Armor.** A tee or wye pressure splice may be made by first making staggered conductor splices with communications connectors, shielding separate pairs if necessary, and rebuilding an overall conductor shield. Build up the bulk of the splice body without allowing spacer tape to cover the end of the armor of the cables entering the splice. Cut off the armor on each cable not less than 1 inch (2.54cm) beyond the end of the outer jacket of the cables entering the splice. Wrap a strip of electrical grounding braid one turn around the armor of one of the cables entering the splice. Solder the braid to the armor. Wrap the grounding braid one turn around the armor of the other two cables entering the splice and cut off. Solder the braid to the armor of the two cables. Clean and scrape the outer jackets of the cables at least 3 inches (7.62cm) beyond the end of the cable outer jacket. Apply at least two layers of spacer tape over the grounding braid and braid anchor before encapsulating the splice body in polyurethane compound.

(k) Polyurethane-Compound-Poured, In-line Splice Kit Application.

1 Insulation Preparation. Strip the insulation from the ends of the conductors to be spliced with compression type in-line connectors. Communications types connectors may be used to splice small conductors without having to strip insulation. Stagger all conductors. The insulation does not have to be penciled.

2 Conductor Pair Shielding. The braided shield covering each of one or more pair splices within a poured compound splice kit should be rebuilt in a manner similar to the method shown by figure 5-27, step 2, for a pressure splice. The mylar-backed, aluminum foil shield for a conductor pair splice within a poured compound splice kit, should be rebuilt in a manner similar to the method shown by figure 5-29, step 2, for a pressure splice. Rebuild the shields with a section of braided, tinned copper shielding material. Each shielded pair splice should be covered with one half-lapped layer of vinyl tape to prevent its shield from touching the shield of adjacent shielded pairs.

3 Splice Encapsulation. Follow the splice kit instructions, as shown by figure 5-16, to clean the cable jacket, assemble the shell mold, and pour the polyurethane compound into the splice body.

(l) Polyurethane-Compound-Poured, Wye Splice Kit Application.

1 Insulation Preparation. Do not remove or pencil the conductor insulation if communications type insulated connectors are used to connect the three conductor ends together. If a compression connector is used to splice three conductor ends together, remove the insulation from the end of the three conductors and do not pencil the insulation. Stagger the connectors and insulate each connector with screen spacer tape if necessary.

2 Conductor Pair Shielding. Remove each braided copper or aluminum-mylar pair shield from the splice area, as shown by figures 5-27, step 1, and 5-29, step 1. Bend copper drain wires of aluminum-mylar shields away from the splice area. Wrap one half-lapped layer of screen spacer tape over the conductors and connectors between the cut ends of the pair shields. Wrap a half-lapped layer of braided, tinned copper shielding over the screen spacer tape and over the ends of the pair shielding. Tack-solder the wrapped braid to copper-braid pair shields. Twist the ends of the drain wires of aluminum-mylar pair shields together and solder. Tack-solder the twisted drain wires to the wrapped braid, then encapsulate the splice. If two or more shielded pairs are to be spliced, separately wrap each bundled conductor pair and its connectors with braided, copper shielding and tack-solder to the pair shield or drain wire. Separate the shielded pairs with screen-spacer-tape wedges, then encapsulate the splice. If each cable end has two or more pairs whose shields are insulated from each other, wrap one half-lapped layer of screen spacer tape around the wrapped shield of each pair splice. Separate the shielded pairs with screen-spacer-tape wedges, then encapsulate the splice.

3 Splice Encapsulation. Follow the wye splice kit instructions, which are similar to the in-line splice (figure 5-16), to clean the cable jackets, assemble the mold body around the splice, and pour the polyurethane compound into the splice body.

(3) Control and Telephone-Type Cable Splices, Typical.

(a) Single-Pair Cable With Braided Shield. Figure 5-27 shows the construction of a splice for a single shielded pair. The method shown to rebuild the shielding is applicable for a tee or wye pressure splice or for a wye poured splice, by wrapping electrical shielding tape over the conductors and communications type connectors, then soldering to the shields of the cable ends. This in-line splice shown by figure 5-27 may be dry spliced (tape) or may be encapsulated by a pressure or poured compound splice body.

(b) Single-Pair Cable With Mylar-Backed, * **Aluminum Foil Shield.** Figure 5-29 shows the construction of a splice for a single shielded pair. The method shown to rebuild the shielding is applicable for a tee or wye pressure splice, or for a wye poured splice, by wrapping electrical shielding tape over the conductors and communications type conductor connectors, then soldering to the bare copper grounding wire of the foil shielding. The in-line splice shown by figure 5-29 may be dry spliced (taped) or may be encapsulated by a pressure or poured compound splice body.

(c) Multiconductor Shielded and Armored Cable Pressure Splice. Figure 5-28, step 1, shows a multiconductor cable with aluminum-tape-wrapped overall conductor shielding and steel-tape-wrapped armor. Splice dimensions shown are for cables with as many as 101 pairs or 202 conductors. The conductors should be spliced with staggered in-line or communications type connectors. Cut the aluminum shield to one-half its width so as to allow compound penetration into the spacer-tape covered and bundled conductors and connectors. Since soldering aluminum is difficult, use pliers to form a crimp pocket on the ends of the shield tapes when they are to be joined to cover the splice body, as shown by figure 5-28, step 3. Put an antioxidant grease into the crimped ends of the shield tapes before they are crimped together. Wipe off excess grease. After wrapping at least two layers of screen spacer tape over the shield tapes, use electrical grounding braid to provide armor electrical continuity, as shown by figure 5-28, step 4. The braid should be wrapped at least one turn around the armor of the cables entering the splice and soldered to the armor. The armor may be grounded by a section of grounding braid soldered to the armor on one side of the splice. Solder-block the braid and anchor it to the outer jacket with vinyl tape or electrical putty tape, as shown by figure 5-30, step 2. Extend the splice body at least 3 inches (7.62cm) beyond the end of the outer jackets on each side of the splice. Encapsulate the splice body with polyurethane compound.

(d) **Multiconductor, Armored Cable Pressure Splice.** Figure 5-30, step 1, shows a multiconductor cable with a corrugated armor. Dimension C of figure 5-28, step 1, may be used for various cables having up to 202 conductors. Armor continuity and grounding must be as shown by figure 5-30, step 2. Build up the splice body with screen spacer tape and encapsulate it with polyurethane compound. This splice is not suitable for encapsulating in a poured compound kit because of the need to ground the armor.

f. Solid-Dielectric Coaxial Cable Splicing, General Practice.

(1) **Solid-Dielectric Coaxial Cable Splice Preparation.**

(a) **Cutting Cable Ends.** The ends of the coaxial cable should be cut off square. If a damaged cable is buried without available slack, use two splices in repairing it. When replacing a section of buried cable, provide a minimum loop of 3 feet (0.91 meter) in addition to the length of cable required for the two splices.

(b) **Outer Jacket Cleaning.** Clean the outer jacket on both sides of the splice prior to making the splice. It may be more convenient to clean the outer jacket before removing it from the cable ends to be spliced. A knife held perpendicular to the cable and pulled as a scraper is one of the best cleaning methods to remove dirt, wax, plasticizers, and other residues. A rasp or aluminum oxide cloth should be used for further cleaning and for roughing up the outer jacket surface. Failure to clean the jacket results in a weak tape or polyurethane-compound bond and a possible moisture path. The cleaned jacket may be covered with vinyl tape having a nonmigrating adhesive, equal to Scotch 33, for protection during the splicing operation.

(c) **Outer Jacket Removal.** Remove the outer jacket to expose the armor or braided shield (outer conductor). Use a sharp knife or cable stripping tool to score the cable jacket approximately halfway through its thickness. If the jacket cannot be peeled and pulled from the cable, cut through the jacket, taking care not to nick the armor or braided outer conductor.

(d) **Armor Removal.** Remove the armor from the ends of the coaxial cables to be spliced. A convenient way to hold the armor before and after removal is to place an adjustable, flat hose clamp over the armor, close to the end of the outer jacket. The clamp can be placed where the armor is to be cut, and thus act as a cutting guide. If the clamp is too large for the diameter of the cable, layers of vinyl tape may be wrapped directly over each other, with the tape edge nearest the cable end marking where the armor is to be cut. Score the armor with a hacksaw blade at the edge of the clamp or edge of the layered tape nearest the cable end. Unwrap the armor and break off at the score mark. Leave the clamp or tape in place until its removal is required to build the splice.

(e) **Outer Conductor (Shield) Removal.** Wrap the braided shield with layered vinyl tape. The tape edge nearest the splice should mark where the braid is to be cut. Cut and trim the braid with scissors. Some splices require shield removal from the cable end on only one side of the splice.

(f) **Dielectric Removal.** Remove the dielectric by first cutting through most of its thickness, then pulling the dielectric from the conductor. If a conductor strand is severed or is broken when removing the dielectric, cut off the end of the dielectric and conductor, then start the splice preparation again for that cable end. Do not attempt to splice a stranded conductor with one or more strands missing.

(2) Solid-Dielectric Coaxial Cable Splice Buildup.

(a) Coaxial Connector Kit Splice. Solid-dielectric coaxial cable, having either one or two center conductors in addition to a braided outer conductor (shield), can be spliced with a connector kit furnished by various manufacturers. The connectors are generally used for splicing where the splice will not be subjected to moisture penetration. However the connectors may be used when encapsulated in a pressure or poured polyurethane-compound splice to prevent moisture penetration. The manufacturers' instructions include removal of the cable jacket from the cable ends, removal of part of the outer conductor, and removal of part of the cable dielectric to expose the end of the center conductor(s). The center conductor(s) is usually soldered to the center pin(s) of the connector, and the outer conductor is soldered or clamped to the connector body. Both cable ends are fastened to one-half of the connector. The male and female halves of the connector lock or thread together to complete the splice. If the connector is to be encapsulated, remove at least 3 inches (7.62cm) of outer jacket adjacent to the connector body on each cable end. Scrape the outer jacket 2 inches (5.08cm) beyond the ends of the poured in-line splice kit shell to be used. Clean the exposed cable shield and outer jacket with a lint-free cloth moistened with trichloroethane. It is necessary that the shield be clean enough for the poured compound to form a moisture seal between the shield and the cable dielectric beneath the shield. Wrap the connector body with two layers of vinyl tape, using care not to cover the braided shield where it enters the splice connector body. Place the splice kit shell over the splice and mix the polyurethane compound. Elevate one end of the splice so that as the compound is poured into the funnel on the lower end of the splice shell, air will not get trapped by the compound being poured too fast. The splice should not be moved until the compound has hardened. The connector may be weatherproofed adequately without encapsulating for installation where the cable will not be subjected to water immersion. Wrap the connector and the cleaned outer jacket with two half-lapped layers of vinyl tape. The tape wrap should be coated with electrical coating or spray sealer and allowed to dry.

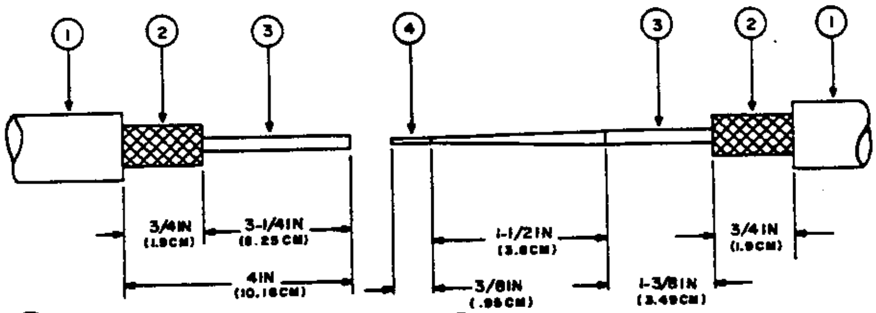
(b) Splice Buildup Methods.

1 Inner Conductor Splicing.

a Solid Inner Conductor. A crimp or solder in-line sleeve connector may be used to connect the inner conductors together when building the splice, as shown by figure 5-31, step 2. The outer diameter of the connector should be as small as possible to minimize the change in cable impedance at the splice. File off excess solder when using a solder sleeve connector. Figure 5-32, step 4, shows that a solid inner conductor may be butt connected by bias cutting and soldering. File or cut each conductor end at a 60° angle and tin the angled surfaces with 60-40 solder. File off excess solder when the solder cools. Place the conductor ends together and bind them with a spaced wire wrap, as shown by figure 5-32, step 4. Apply 60-40 solder to the splice and, while the solder is still molten, grasp the splice at the center with needle-nose pliers and squeeze it to drive excess solder from the mating end surfaces. Withdraw the soldering iron and allow the splice to cool before releasing the pliers. Remove the binding wire and scrape or file excess solder from the splice. This type of splice, when used to join large solid inner conductors, may be strengthened by drilling one or two holes through the bias cut surfaces of the splice junction while it is bound or held together before soldering. Put a short piece of copper wire through each hole and bend or peen on both sides of the splice. Apply solder, allow it to cool, and then remove the binding wire. File off excess solder and the ends of the copper wires flush with the outside of the splice. A step-cut splice may be made in a similar manner by filing off half the diameter of each conductor for approximately ½ inch (1.27cm) from each conductor end.

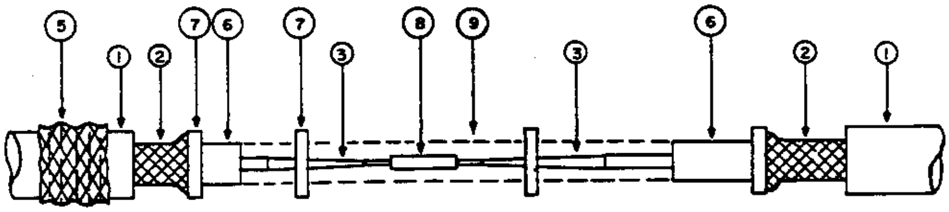
b Stranded Inner Conductor. Figure 5-32, step 2, shows that part of the strands are to be cut away from the inner conductor of each cable end. The strands of the inner conductors should be overlapped and held while a binding wire is wrapped around the overlap, as shown by figure 5-32, step 3. The turns of the binding wire must be spiral-wound, as shown. Use a 60-40 resin-core solder to solder the strands and binding wire together. After the solder has cooled, peel the binding wire from the soldered strands. Remove excess solder from the strands with a knife or file to make the soldered

STEP 1.



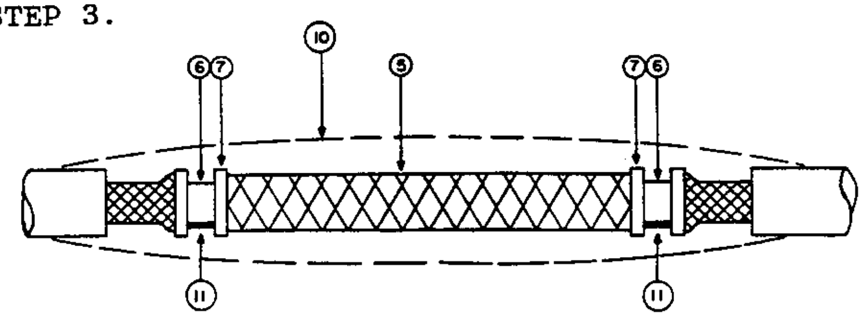
(1) OUTER JACKET
(2) COPPER BRAID OUTER CONDUCTOR
(3) DIELECTRIC
(4) STRANDED CONDUCTOR

STEP 2.



(5) 8 IN (20.32CM) SECTION OF BRAIDED, TINNED COPPER SHIELDING WITH 1/2 IN (1.27CM) NOM. I.D.
(6) GROUND SHEATH CONNECTOR (INNER SLEEVE), BURNDY NO. YOC200-G3, OR EQUAL.
(7) GROUND SHEATH CONNECTOR (OUTER SLEEVE), BURNDY NO. GSC500, OR EQUAL.
(8) COMPRESSION CONNECTOR, NICOPRESS NO. 3-036A (DRILLED OUT WITH #55 DRILL), OR EQUAL.
(9) VINYL TAPE OVER SPLICE

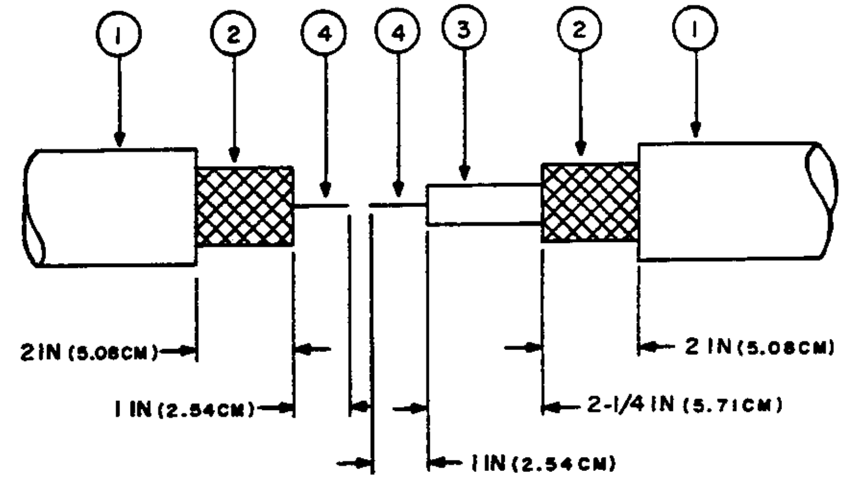
STEP 3.



(10) VINYL TAPE
(11) SOLDER FILLET

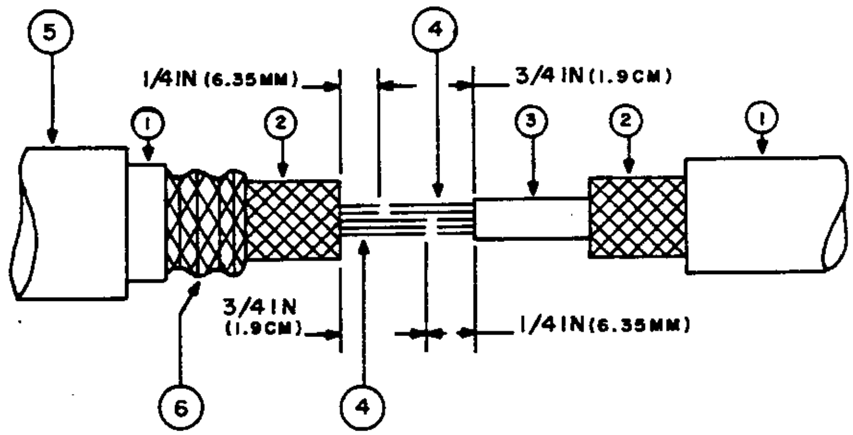
Figure 5-31. Taped Splice For RG-11A/U Coaxial Cable.

STEP 1.



1 OUTER JACKET
2 OUTER CONDUCTOR (COPPER BRAIDED SHIELD)
3 INNER CONDUCTOR DIELECTRIC (INSULATION)
4 INNER CONDUCTOR, SOLID OR STRANDED

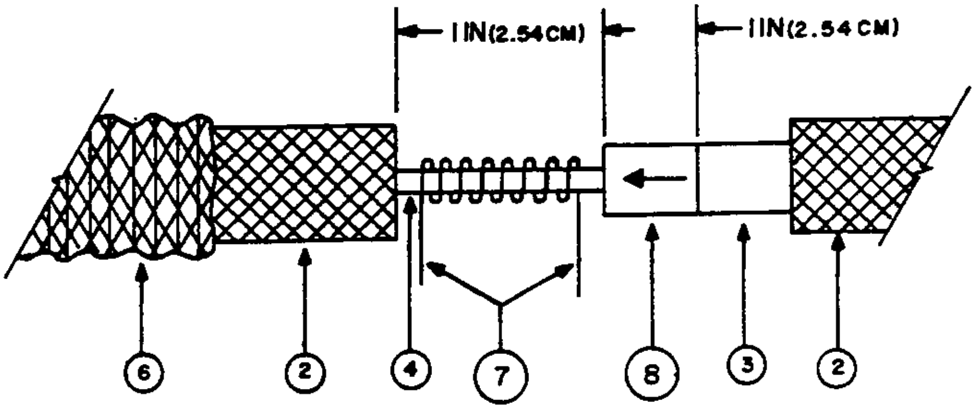
STEP 2.



4 STRANDED INNER CONDUCTOR, CUT OFF
5 10 IN (25.4CM) SECTION OF THICK-WALL HEAT-SHRINK TUBING
6 5 IN (12.7CM) SECTION OF BRAIDED, TINNED COPPER SHIELDING (COMPRESSED)

Figure 5-32. Heat-Shrink Tubing Method For Splicing Unarmored Solid/Dielectric Coaxial Cable.

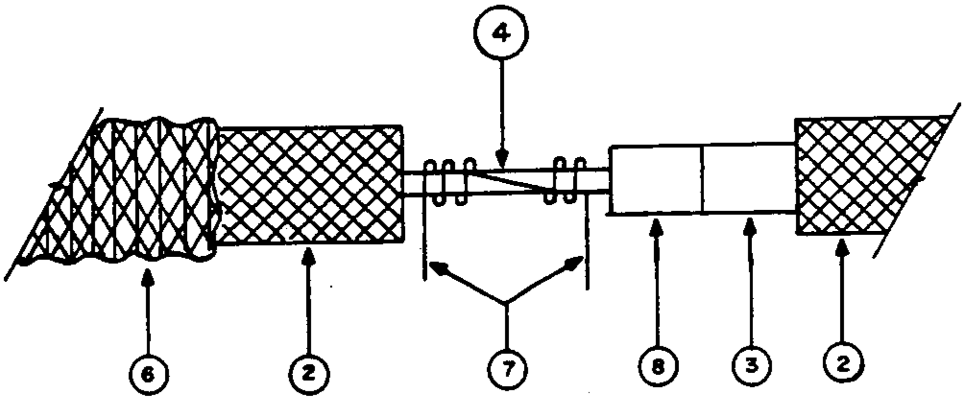
STEP 3.



7 BINDING WIRE

8 DIELECTRIC SEVERED FROM 3

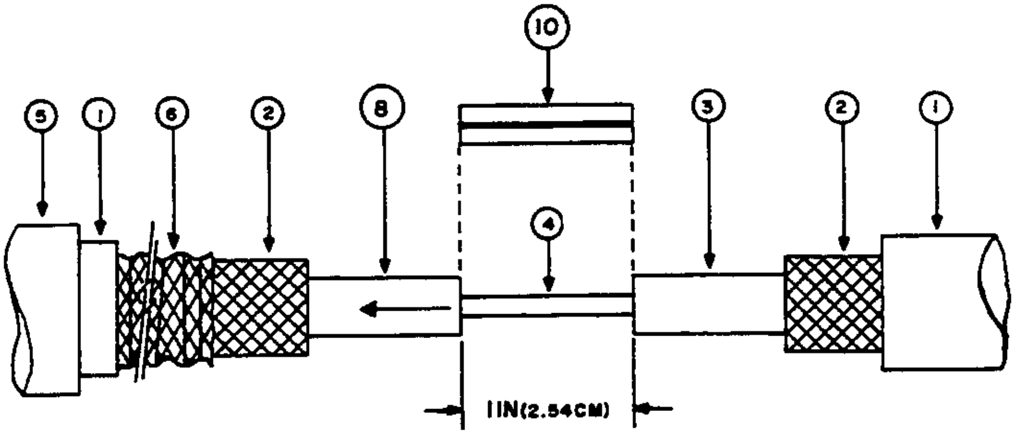
STEP 4.



4 SOLID INNER CONDUCTORS, BIAS CUT

Figure 5-32. Heat-Shrink Tubing Method For Splicing Unarmored Solid-Dielectric Coaxial Cable — continued.

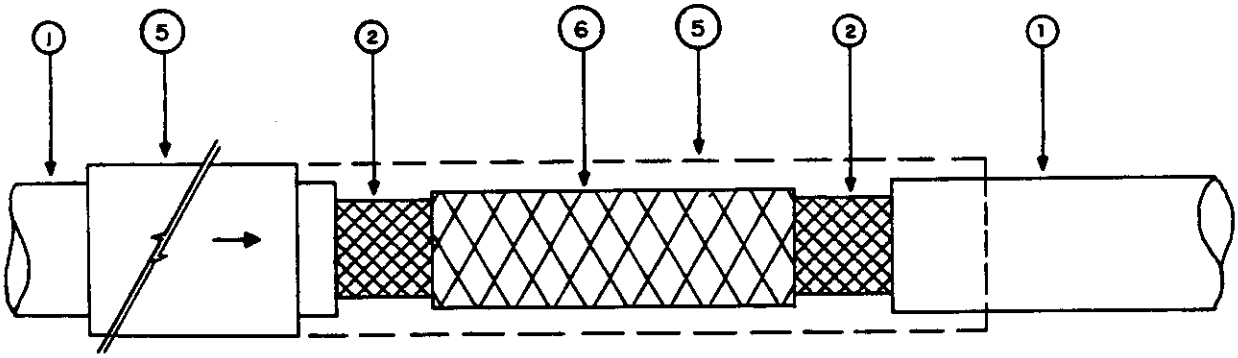
STEP 5.



(8) DIELECTRIC MOVED TO COVER CONDUCTOR SPLICE

(10) 1IN(2.54CM) SPLIT SECTION OF DIELECTRIC MATERIAL

STEP 6.



(5) 10IN(2.54CM) SECTION OF THIN-WALL TUBING HEAT SHRUNK OVER SPLICE.

(6) 5 IN (12.7CM) SECTION OF BRAIDED, TINNED COPPER SHIELDING (TACK SOLDERED)

Figure 5-32. Heat-Shrink Tubing Method For Splicing Unarmored Solid-Dielectric Coaxial Cable — continued.

junction as smooth as possible and to keep its diameter to a minimum.

2 Dielectric Replacement.

a Dielectric Material. Figure 5-32, step 5, shows a splice where a piece of dielectric material from a similar cable has been cut to length, split lengthwise, and inserted into the soldered splice area for dielectric buildup.

b Butyl Compound Material. Figures 5-33, step 2, and 5-34, step 3, show splices where a butyl sealing and dielectric compound has been used to build up the cable dielectric in the splice area.

c Vinyl Tape. Figure 5-31, step 1, shows a splice with vinyl tape used to build up the dielectric in the splice area; and figure 5-31, step 3, shows that vinyl tape is used to build up the splice body.

3 Outer Conductor (Braided Shield) Replacement. Figures 5-31, step 3, and 5-32, step 6, show splices where pieces of braided, tinned copper shielding material have been used to build up the outer conductor of a splice. Figures 5-33, step 1, and 5-34, step 1, show that the original outer conductor on one of the cable ends has been pushed out of the way (compressed) during part of the splicing procedure, then stretched over the connector and dielectric to rebuild the outer conductor. Figure 5-31 shows a splice made by using solder sleeves and compression rings to build up the outer conductor over an inner conductor sleeve connector and taped dielectric.

4 Inner and Outer Jacket Replacement.

a Thin-Wall Heat-Shrink Tubing. Figures 5-32 (step 6), 5-33 (steps 2 and 4), and 5-34 (step 5) show how heat-shrink tubing material is used to build the splice. Figures 5-33, step 2, and 5-34, step 4, show that thin-wall tubing is shrunk directly over the dielectric material at the splice. Figure 5-33, step 4, shows that thin-wall tubing is used to build the inner jacket by shrinking over the outer conductor (braided shield) of an armored cable.

b Thick-Wall Heat-Shrink Tubing. Figures 5-32 (step 6), 5-33 (step 4), and 5-34 (step 5) show that thick-wall tubing is shrunk over the complete splice area for moisture and abrasion protection.

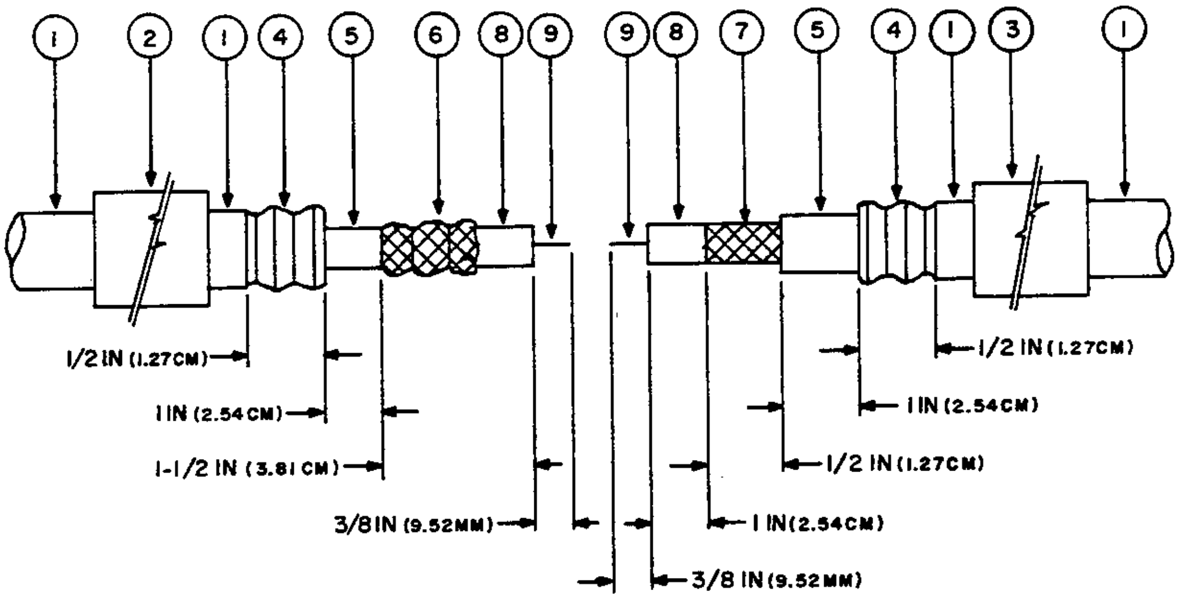
5 Poured Splice Encapsulation. All of the built-up splices shown may be encapsulated in polyurethane compound material. If this method is chosen, the thin-wall heat-shrink tubing used to cover the inner conductor should be left out of the armored cable splice, shown by figure 5-33, step 4. The vinyl tape outer jacket buildup (figure 5-31, step 3) and the thick-wall tubing outer jacket buildup [figures 5-32 (step 6), 5-33 (step 4), and 5-34 (step 5)] should not be included with the splice. Clean and scrape the outer jacket beyond the splice area for good adhesion of the poured polyurethane-compound material. Cut back the inner jacket of the armored splice, shown in figure 5-33, step 1, to allow more area of contact between the inner conductor and the poured compound. The outer conductor must be clean to allow proper penetration.

(3) Solid-Dielectric Coaxial Cable Splices, Typical

(a) Taped Splice for RG-11A/U Unarmored Cable. Figure 5-31 shows the steps necessary to build this splice. The outer diameter of the compression connector is slightly larger than the diameter of the center conductor of the cable. Drill out the connector to fit the center conductor. Pencil the cable dielectric to provide a taper for dielectric buildup with vinyl tape. Insert a sleeve (item 6 of figure) between the dielectric and outer conductor on each cable end. Replace the outer conductor with a section of braided tinned copper shielding material (item 5 of figure). Join the shielding material and the outer conductor at each cable end by the sleeve. Split the outer sleeve rings (item 7 of figure) with cutting pliers and crimp over the braided outer conductor and shielding material to hold them tight on the sleeve. Make a fillet of 60-40 solder between the two sleeves at each end of the splice to provide better electrical continuity. Replace the outer jacket by layers of vinyl plastic tape.

(b) Heat-Shrink Tubing Splice for RG-11A/U Armored Cable. Figure 5-33 shows dimensions and materials for this splice. Connect the inner conductors together with an in-line crimped and soldered connector, 3M Catalog No. B-42-201 or equal. The butyl dielectric material (item 11 of figure) should be * equal to AMP Catalog No. 602282 or Sigmaform tape sealant series SFTS. The .750 expanded inside-diameter (id), .375 recovered id, thin-wall heat-shrink tubing without sealant should be equal to AMP Catalog No. 603329-1 or Sigmaform series STW. The .750 id, .220 recovered id thick-wall heat-shrink * tubing with end sealant should be equal to

STEP 1.



(1) OUTER JACKET

(2) 12 IN (30.48CM) SECTION OF THICK-WALL HEAT-SHRINK TUBING

(3) 6 IN (15.24CM) SECTION OF .750 EXPANDED I.D. THIN-WALL HEAT-SHRINK TUBING

(4) CORRUGATED COPPER ARMOR

(5) INNER JACKET

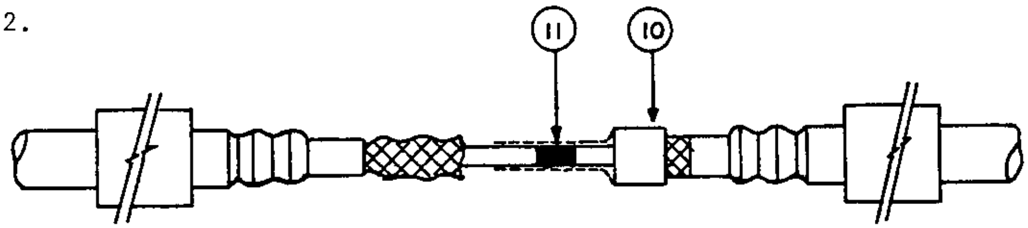
(6) OUTER CONDUCTOR (COPPER BRAIDED SHIELD), 4-1/2 IN (11.33 CM) LONG, PUSHED BACK TO COMPRESS

(7) OUTER CONDUCTOR (COPPER BRAIDED SHIELD), ON RIGHT SIDE

(8) INNER CONDUCTOR DIELECTRIC (INSULATION)

(9) INNER CONDUCTOR

STEP 2.

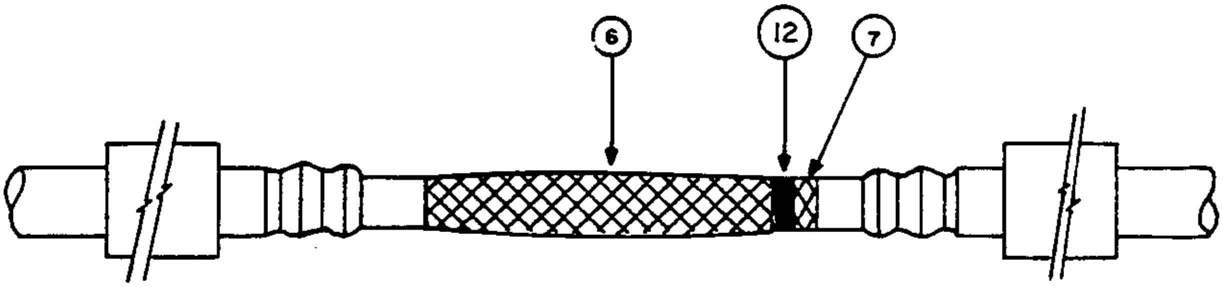


(10) 2-1/2 IN (6.35CM) SECTION OF .500 EXPANDED I.D. THIN-WALL HEAT-SHINK TUBING

(11) BUTT-CONNECTED AND SOLDERED INNER CONDUCTORS, COVERED WITH BUTYL DIELECTRIC MATERIAL

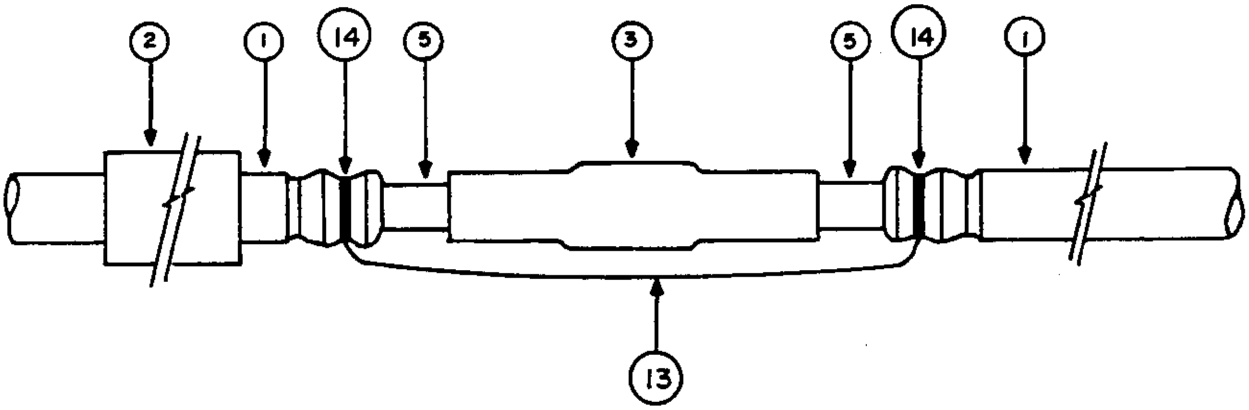
Figure 5-33. Heat-Shrink Tubing Method For Splicing Armored RG-11A/U Coaxial Cable.

STEP 3.



(12) BUTYL RUBBER MOISTURE BLOCK AT LEFT OF TACK-SOLDERED OUTER CONDUCTORS

STEP 4.

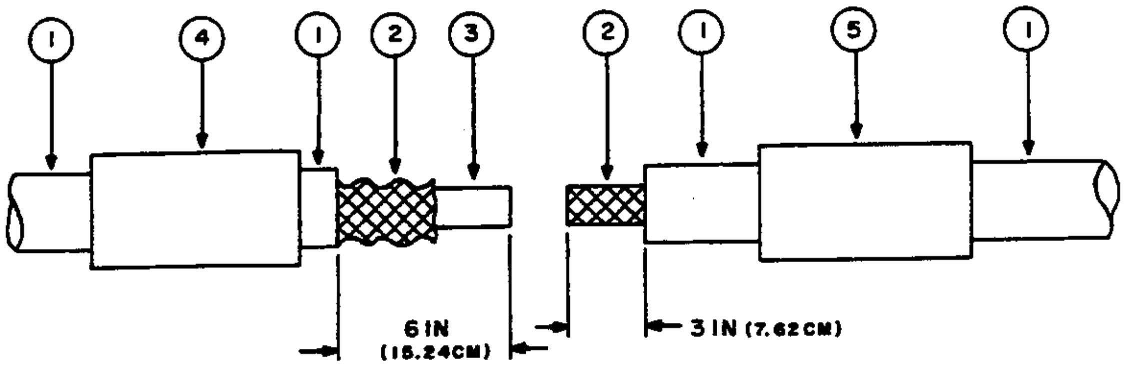


(13) NO. 14 BARE COPPER BONDING WIRE

(14) SOLDER TERMINAL OR NO. 14 BONDING WIRE WRAP

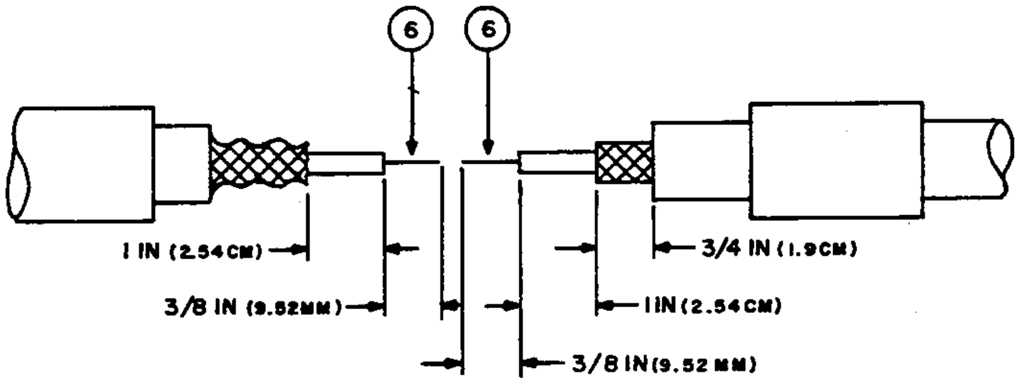
Figure 5-33. Heat-Shrink Tubing Method For Splicing Armored RG-11A/U Coaxial Cable–continued.

STEP 1.



(1) OUTER JACKET
(2) OUTER CONDUCTOR (COPPER BRAIDED SHIELD), PUSHED BACK ON LEFT SIDE TO COMPRESS
(3) INNER CONDUCTOR DIELECTRIC (INSULATION)
(4) 12 IN (30.48CM) SECTION OF THICK-WALL HEAT-SHRINK TUBING
(5) 2-1/2 IN (6.35CM) SECTION OF .500 EXPANDED I.D. THIN-WALL HEAT-SHRINK TUBING

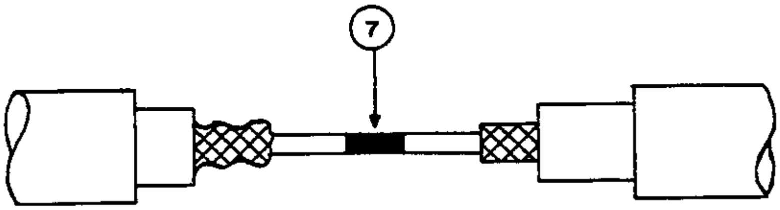
STEP 2.



(6) INNER CONDUCTOR

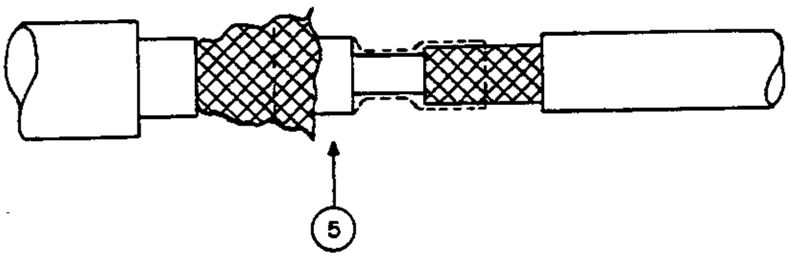
Figure 5-34. Heat-Shrink Tubing Method For Splicing Unarmored RG-11A/U Coaxial Cable.

STEP 3.



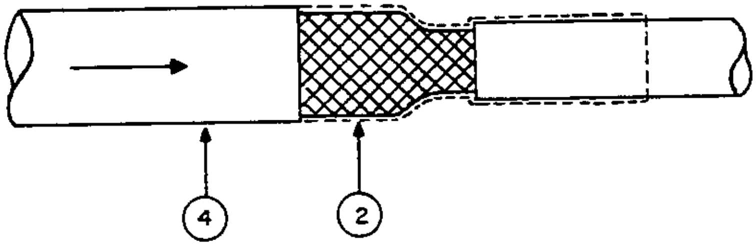
(7) CONDUCTOR CONNECTOR, COMPRESSED AND EXCESS SOLDER REMOVED, COVERED WITH BUTYL DIELECTRIC MATERIAL

STEP 4.



(5) THIN-WALL TUBING CENTERED OVER SPLICE AND HEAT SHRUNK

STEP 5.



(2) OUTER CONDUCTOR (SHIELD) STRETCHED OVER SPLICE. CUT OFF EXCESS AND TACK SOLDER

(4) THICK-WALL TUBING OVER ENDS OF OUTER JACKET AND HEAT SHRUNK

Figure 5-34. Heat-Shrink Tubing Method For Splicing Unarmored RG-11A/U Coaxial Cable — continued.

* AMP Catalog No. 6030/0-1 or Sigmaform series SST. * Apply the butyl rubber moisture block (item 12 of figure) over the tack-soldered junction of the outer conductor at the cable end. Electrical putty may be used for this solder block. Move the thin-wall tubing over the braided conductor and heat shrink. Wrap the bare copper armor bonding wire or grounding braid around the armor and solder. Bonding strap terminals equal to AMP Catalog No. 329860 may be used instead. Cover the splice with thick-wall heat-shrink or prestretched tubing which does not require heat for shrinking. A flameless heat gun should be used to provide at least 250°F (121°C) hot air to shrink the tubing. This splice may be encapsulated with poured polyurethane compound by eliminating the heat-shrink tubing (items 2 and 3 of figure 5-33) if the outer jacket is cleaned and roughened beyond the ends of the poured splice kit shell.

(c) **Heat-Shrink Tubing Splice for RG-11A/U Unarmored Cable.** This splice is shown by figure 5-34, steps 1 through 4. Join the conductors together with an in-line crimped and soldered connector. 3M part No. B-42-201 or equal. The butyl dielectric material (item 7 * of figure) should be equal to AMG Catalog No. 602282 or Sigmaform tape sealant series SFTS. The .500 expanded id, .250 recovered id, thin-wall heat-shrink tubing without sealant should be AMP Catalog No. 603328-1 or Sigmaform series STW. Compress the outer conductor item 2 of figure) on one cable end to clear the splice area, then stretch and tack-solder it to the outer conductor on the other cable end. Cover the splice area with .750 expanded id, .220 recovered id, thick-wall heat-shrink tubing with end sealant, equal to AMP Catalog No. 603070-1 or Sigmaform series SST. A 250°F (121°C) flameless heat gun should be used to * shrink the tubing. This splice may be encapsulated in poured polyurethane compound, if the outer jacket is cleaned and roughened beyond the ends of the poured splice kit shell. (See figure 5-16.)

(d) **Heat-Shrink Tubing and Soldered Splice for Unarmored Cable.** Figure 5-32 shows a splice that may be used for several types of unarmored solid-dielectric coaxial cable. The outer conductor is built with the outer conductor from one cable end and with an additional piece of braided, tinned copper shielding material, having a nominal id equal to the diameter of the cable dielectric. This splice method provides for solder connecting the stranded or solid inner conductor. Cut the stranded conductors so as to overlap each other. Use a short wire (item 7 of figure) to hold the overlapped ends of the conductors together for soldering purposes. After soldering peel the wire from the soldered conductors and remove excess solder from the splice. The splice for large solid conductors can be strengthened by drilling one or two holes through both conductor ends in the beveled or notch-cut area while they are bound with the spiral-wrapped wire before soldering. Insert a short piece of copper wire in each drilled hole, bend or peen the ends of the short piece of wire, then apply solder to the conductor junction. Remove excess solder and file the bent or peened ends of the copper wires to make the splice smooth. Peel off the binding wire and remove excess solder. Ring-cut a short section of the cable dielectric on one cable end to free it from the dielectric. Slide this short section over the soldered conductor junction. Cut a section of dielectric material from a similar coaxial cable, split it lengthwise, then tightly wedge it into the splice area to replace the gap in the dielectric. Fuse this section of dielectric material along its lengthwise split with an oxide-free hot soldering iron tip. Cover the completed splice with .750 expanded id, .220 recovered id, thick-wall tubing, and shrink it with 250°F (121°C) flameless heat. This splice may be encapsulated in a polyurethane-poured splice if the heat shrink tubing is not installed.

59. POWER CABLE TERMINATIONS, 5KV AND 15KV.

a. General. A high-voltage cable termination is a device used for terminating alternating current power cables having laminated or extruded insulation rated 2.5kV and above. A cable termination performs three basic functions:

(1) Provides some form of electric stress control for the cable insulation shield terminus.

(2) Provides complete external leakage insulation between the high-voltage conductor(s) and ground.

(3) Provides a seal to prevent the entrance of the external environment into the cable and to maintain pressure within the cable system. A termination that performs all these functions is a class 1 (IEEE Standard, 48-1975) termination. This classification encompasses the conventional potheads for which the original IEEE Standard 48-1962 was written. A class 2 termination is one that provides only functions 1 and 2 above; a class 3 termination provides only function 1 above.

NOTE: Absolute cleanliness should be observed when terminating a high-voltage

* cable. Dirt, semiconducting materials, moisture, and skin oils trapped inside the termination during its construction can cause its destruction by arcing or flashover. *

b. **Terminating Materials.** A high voltage cable can be terminated with a stress cone, a cable terminator, or a pothead. Stress cones can be bought in a kit form or can be built using electrical tapes. The materials used to teminate the end of a high voltage cable are those required to insulate the cable and to shield the cable end to minimize electrical stress. These materials consist of tapes, pennant kits, cable terminators or terminator kits, and a pothead.

(1) **Tapes.** Semiconducting tape, high-voltage tape, vinyl plastic tape, and electrical shielding tape are used for building stress cones. Figure 5-35 illustrates a typical 5kV or 15kV cable stress cone built from tapes.

(2) **Stress Cone Kits.** Several manufacturers provide kits for stress cone buildup. Termination kits are furnished to build 5kV to 15kV stress cones on No. 8 AWG to 1000 MCM insulated power cables. The kits provide instructions and all stress cone materials required for a complete termination except for conductor lugs.

(3) **Cable Terminator.** Various manufacturers provide single-conductor cable terminators similar in appearance to a pothead, but with only one porcelain insulator. A three-phase cable would require three terminators, which may be either crossarm or pole mounted. Terminators may be used with 5kV and 15kV cables.

(4) **Pothead.** A pothead may be used to terminate a three-phase shielded cable. In essence, it is three porcelain insulated terminals in one assembly. A pothead may be used with 5kV or 15kV multiconductor cables.

(5) **Electrical Grounding Braid.** An electrical grounding braid may be used in lieu of a wire to ground the stress cone, as shown by figure 5-35. A wire or braid is soldered to the metallic shield.

c. Cable Preparation. The end of a cable should be prepared for termination in much the same manner as a cable being prepared to make a splice. The instructions furnished by manufacturers of terminators, kits, and stress cone materials give the details for preparing the various types and sizes of single conductor or multiconductor cables for terminations. Their instructions caution against nicking the conductor and insulation, and stress the removal of contaminants, which may cause failure.

d. Taped Stress Cone Buildup. Figure 5-35 shows a splice diagram of a stress relief cone built from various tapes and provided with a grounding wire and a crimp lug on the end. The tape manufacturer's instructions show dimensions for cables insulated to 15kV.

e. Pothead Assembly. Several steps are required to terminate a three-conductor, shielded power cable with a pothead. Instructions for a typical 5kV cable pothead installation are given below.

(1) Remove the jacket from the cable, leaving the conductors long enough for proper termination in connector terminals.

(2) Install sealing fittings and flange on the conduit. Make sure there is a positive seal around the jacket to prevent filling compound from entering the conduit. If the cable has metallic armor tape, leave approximately 5 inches (12.7cm) of armor past the jacket termination. Thoroughly clean the ends of the armored tape and tin. Fasten the armor to the pothead body with a machine screw with its head on the inside of the pothead body.

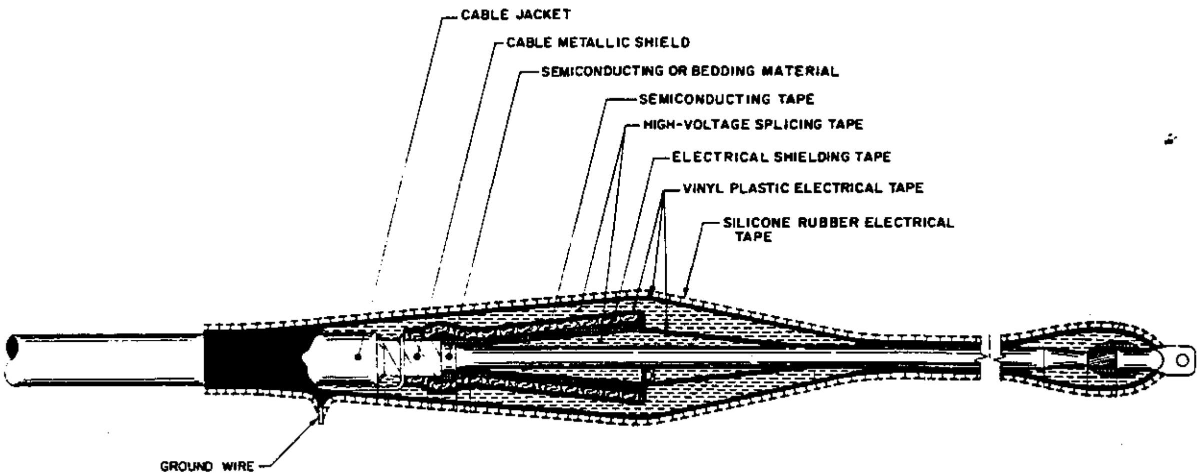


Figure 5-35. Taped Stress Cone Buildup.

(3) Remove identification or any tape from the conductors and scuff the conductor insulation. Properly train the conductors and set the top section of the pothead in place. Mark the length of each conductor at the procelain insulator. Remove the top section of the pothead and measure the distance from the top of the porcelain to the bottom of the soldering well in the connector terminal. Cut each conductor ⅛ inch (31.7mm) longer than its previously marked length to eliminate undue stress on the conductor when the pothead is assembled.

(4) Remove the insulation from the end of each conductor and pencil the insulation. Leave approximately ½ inch (1.27cm) bare copper between the insulation and the connector terminal. Solder the connector terminal to the conductor.

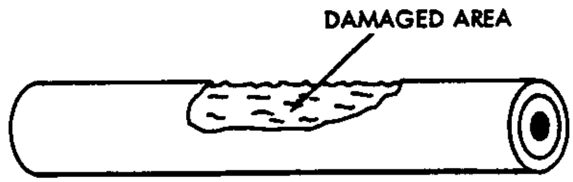
(5) Fit the top section of the pothead in place and tighten all parts except the terminal cap. Make sure the shoulders of the conductor terminals are in place.

(6) Remove the fill and vent plugs. Install a fill pipe to extend approximately 4 inches (10.16cm) above the top of the procelain. Install a vent pipe to extend approximately 1 inch (2.45cm) above the top of the porcelain.

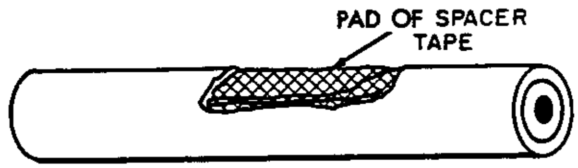
(7) Heat the potting compound with a torch before filling and keep it hot during the filling operation by applying heat to the fill pipe. Be careful not to apply heat directly to the porcelain. The level of the compound should be brought to the top of the procelain: and then pouring continued slowly until the compound stops bubbling and the interior of the porcelain is solidly filled. Replace and tighten the terminal nuts. After the pothead is cool and the compound has solidified, remove the fill and vent pipes and replace the fill and vent plugs. Check tightness of the capscrews and terminal nuts.

60. CABLE JACKET REPAIR.

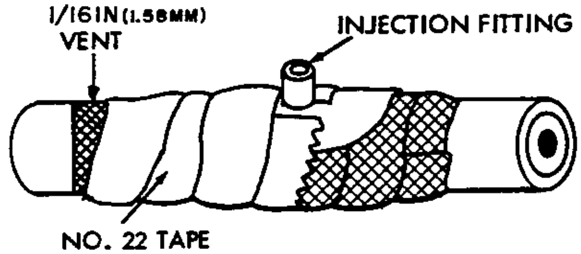
Figure 5-36 illustrates how to repair a damaged outer jacket on a power, control, telephone-type, and solid-dielectric coaxial cable. Sigmaform shrinkaround sleeve series SGR may also be used to repair damaged outer cable insulation. If outer jacket damage to a solid-dielectric coaxial cable extends into the outer conductor (braided shield), remove the outer jacket and repair it with a pressure splice, a poured splice kit, or a heat-shrink tubing splice kit.



STEP 1
THOROUGHLY CLEAN THE SHEATH AROUND THE DAMAGED AREA TO INSURE RESIN ADHESION



STEP 2
FORM A PAD OF SPACER TO NEATLY FIT IN THE DAMAGED AREA.



STEP 3
WRAP SEVERAL LAYERS OF SPACER AROUND THE CABLE AS SHOWN.

STEP 4
LOCATE THE INJECTION FITTING, APPLY THE PLASTIC TAPE ENVELOPE, RESTRICTING TAPE, AND INJECT RESIN.

Figure 5-36. Cable Jacket Repair.

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

DATE:

IN REPLY REFER TO:

SUBJECT: Suggested improvements to Order 6950.22, Maintenance of Electrical Power and Control Cables

FROM:

TO: Chief, Environmental Systems Division, AAF-500

Problems with present order.

Recommended improvements.

Signature

Facility Identifier and AF Address

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